TROPICAL AGRICULTURIST

AGRICULTURAL JOURNAL OF CEYLON

VOLUME CXIII, NUMBER 1, 1957

Edited by

DR. M. F. CHANDRARATNA

Director of Agriculture

DEPARTMENT OF AGRICULTURE, CEYLON

SHAW WALLACE & HEDGES
LIMITED

Specialists in

FERTILISERS
FOR CEYLON CROPS

Sole Suppliers of

STERAMEAL
(Sterilised Animal Meal Black Label)

THE IDEAL DRESSING

for

NURSERIES and YOUNG PLANTS

No. 363, Kollupitiya Road, Colombo 3

Telephone : **78271**

VOL. CXIII, No. 1. MARCH, 1957

CONTENTS

Page

EDITORIAL

Farming in Ceylon's Dry Zone 5

STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

1. The Lateritic Soils on "Bandirippuwa" Estate—A "Lateritic Gravel"

by T. B. Paltridge and K. Santhirasegaram 7

AN ANALYSIS OF EUROPEAN HERDS OF DAIRY CATTLE AT AMBAWELA AND BOPATALAWA

by P. Mahadevan, B.Sc. (Hons.), Ph.D. (Glasgow) 45

INDIGENOUS AND EXOTIC DRUG PLANTS GROWN IN CEYLON

by D. M. A. Jayaweera, B.Sc. (Lond.), M.Sc. (Lond.), F.L.S. .. 55

A COMBINED AUTOMATIC SEED DRILL, FERTILIZER DISTRIBUTOR AND WEEDER FOR MUDLAND PADDY

by C. R. Karunaratna, Dip. Agric. (Wye), Dip. Agric. (Poona) .. 87

METEOROLOGICAL REPORT

Summary for October-December, 1956 97

3——J. N. B 65834 (5/57)

Digitized by the Internet Archive
in 2025

https://archive.org/details/tropical-agriculturist_1957_113_1

EDITORIAL

Farming in Ceylon's Dry Zone

THE SYSTEM of land classification and use implicit in the traditional pattern of peasant agriculture that characterizes the area below the 75-inch rainfall contour (miscalled the 'dry' zone) is almost flawless. Increasing population pressure, however, demands the adoption of techniques that provide higher yields and are less extravagant of land. Moreover, in recent years, the period of rest between successive chenas has, in many parts of Ceylon, become dangerously brief. Under these circumstances, it is difficult to resist the argument that the substitution of the chena by a suitable, settled system of arable farming is unlikely to aggravate damage to soil structure. It is in this context that Government's planned promotion of cotton growing as a component of a rotation should be viewed. Dry-zone land classes with good drainage are, as a rule, eminently suitable for cotton, and where the rainfall during the growing season approximates 25 inches, yields can be almost fantastically high. Land with this happy combination of soil and climate occurs extensively in the Hambantota District. The cotton agronomist should, however, remember that the soil is of a particularly vulnerable type.

The Maha Illupalama Research Station has, during the seven years of existence, accumulated a wealth of information on the properties and performance of dry-zone soils. Probably the most significant finding relates to the soil's structural bonds. These bonds are mainly inorganic, and if destroyed, may be relatively irreparable. The need for preserving structure in dry zone soils, accordingly, needs no emphasis.

Investigations at Maha Illupalama have shown that manuring cannot maintain yields in a soil that has lost its structure. Temperate-climate techniques, like rest under grass leys, are relatively ineffective in restoring fertility in dry-zone soils. The soil-pulverising implements traditional to temperate agriculture have proved particularly destructive. In the last three years, agronomic practices at Maha Illupalama have been revolutionized. Non-inversion tillage with sub-surface sweeps and disc tillers has replaced the old methods of soil

4——J. N. B 65334 (5/57)

inversion with disc ploughs. Moreover, the stubble of previous crops is retained on the soil surface, and mixed cropping is the rule. The new techniques aim at keeping the soil continuously covered and undisturbed. Stubble mulching reduces soil erosion, surface run-off and weeds. Weedicides possess the virtue of achieving weed control with a minimum of interference with the soil, and are likely to assume increasing importance in dry-zone agriculture. It is hoped that this complex of agronomic practices will arrest trends towards loss of soil structure.

Although information on the behaviour of dry zone soils is still relatively incomplete, exhaustive data on crop performance exist. In the dry zone, rainfall in the *maha* season, though unpredictable, is adequate for crop growth, and the choice of crops is wide. The range of suitable cereals includes upland rice, sorghum, maize, kurakkan, cumbu, tanahal and meneri ; the Department has released selections of all these grains. As the Ceylon peasant's diet is notoriously deficient in protein, and as Ceylon imports annually 30 million rupees worth of pulses, considerable interest attaches to the successful breeding and cultivation of cowpea, pigeon pea and numerous other legumes in the dry zone. Oilseeds, fibres and subsidiary food crops will also occupy an important place in rotations.

As the climax vegetation in the undisturbed dry zone is high forest, it may be assumed that both the climate and the soil are suited to the growing of perennials. At present, the choice of perennials is limited to kapok, mango, tamarind and fodder trees. A wide range of economic tree species is, however, under test at Maha Illupalama.

In the primitive pattern of dry-zone agriculture, animal husbandry had no place. There has been, in recent years, a growing realisation that animal husbandry can be a highly profitable industry in the dry zone. The experience of Polonnaruwa Farm is illustrative. Moreover, pastures, like perennials, do not damage soil structure. The extensive establishment of pastures in the " unirrigable lowlands " is strongly urged.

Consequent on the lack of a pastoral tradition, there has been a deficiency in this country, of suitable pasture components. The agrostologist has been compelled to ransack the world's grasslands for promising species, and pasture establishment in Ceylon has been based mainly on two introductions made in the last decade, viz. the grass, *Brachiaria brizantha* from Africa, and the legume, *Stylosanthes* sp. from Australia.

STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

1. The Lateritic Soils on "Bandirippuwa" Estate
A. "Lateritic Gravel"

By T. B. PALTRIDGE and K. SANTHIRASEGARAM
(Coconut Research Institute, Ceylon)

INTRODUCTION

THESE STUDIES were initiated by the Senior author, working under a Colombo Plan Assignment to study two things in Ceylon: (1) the development and management of pastures that might be grown on coconut estates and used to provide meat and milk; (2) the maintenance and improvement of soil fertility in areas where the one crop (coconuts) has been, and possibly will be grown for hundreds of years.

The primary objective has been to determine the nutrient status of selected soils, typical of comparatively large areas, with a view to more effective use of fertilizers on coconuts, and to correction of nutrient deficiencies that might be a limiting factor in the growth and selection of desirable pasture plants. Preliminary studies have been confined to important soils in the immediate vicinity of the Coconut Research Institute (Bandirippuwa Estate), Lunuwila, and this bulletin describes experiments with only one soil.

On any one type of soil, samples were taken from twenty to thirty different places and they were thoroughly mixed to provide uniform material for use in a series of experiments. Unless otherwise stated all samples were taken to a depth of nine inches and only the coarser vegetable matter (leaves, stems and larger roots) were excluded.

The investigation has used a technique of bio-assay (popularly known as the "pot technique") whereby species known to require soils of high fertility are grown in pots with and without mineral nutrients, or combinations of nutrients, and their effect is measured in terms of the yield (dry weight) of plants in every pot. The test plants were all perennial pasture grasses or legumes: they were used deliberately to obtain some basic information in reasonable time.

While all plants (including coconuts) do not require the same nutrients in the same proportions, these experiments should give

a general picture of local soil fertility problems, and it is at least highly probable that if a rapidly growing plant with high fertility requirements shows no deficiency of any nutrient, then that nutrient is unlikely to be a limiting factor in the growth of coconuts.

Three species, one a grass *Paspalum commersonii* Lam (1) and two legumes (*Phaseolus lathyroides* L) and lucerne (*Medicago Sativa* L) have been used. They were selected primarily for their known demand for all essential nutrients and because the senior author was familiar with deficiency symptoms in those species. In all experiments using legumes the soils were inoculated with specially imported strains of *Rhizobium*.

The investigation has used a number of factorial experiments in which many nutrients were applied singly and in all possible combinations. In any one experiment, individual nutrients, or combinations of nutrients were applied to only one pot, but any comparison of treatments was made on the basis of mean values for a large number (normally thirty-two pots, or multiples of that number) to which a particular nutrient had been applied and for the same number of pots without that nutrient. Interactions (the combined effect of two or more nutrients) were measured on the basis of mean values for groups of 16 or 8 pots, or multiples of those numbers. This technique has some advantage over any direct comparison, because each treatment is evaluated over a whole range of conditions with respect to presence or absence of other nutrients.

In any one experiment all pots contained the same amount (normally 2,000 gms. dry weight) of soil, and with the exception of $CaCO_3$ all nutrients were applied in solution. Dosage (i.e., the amount of nutrient applied) was calculated on the basis of lb. (or cwt.) per acre. Stock solutions—with "X" m.l. per pot "Y" lb. (or cwt.) per acre—were prepared, and appropriate quantities were added to a set of beakers representing each treatment in any one experiment. These solutions were then diluted to 250 m.l., and subsequently transferred to pots of soil. All plants were grown from seed, and after germination seedlings in excess of one, uniform plant per pot were removed.

All pots were watered daily, their water content being brought to constant level (85 per cent. field capacity) by weight. In order to avoid contamination, that water was filtered, passed through a commercial water softener, distilled and redistilled before use. The final distillation was in "Pyrex" glass. The pots were 6″ flower pots made of "Polysterien", with no drainage hole in the bottom.

The plants were grown in a special "Phytosolarium", which was a building 20 ft. × 60 ft. made with all-alluminium frame work and

covered with an envelope of "cascalite" (fritted glass in plastic). The sides of this building, above bench height, were hinged to allow free ventilation, and temperatures ranged from a mean maximum of 108°F. in April and May to 104°F. in August. Minimum temperatures were from 70° F. in May to 77° F. in August. Light was diffuse and remarkably even, and the plants showed no symptoms of inadequate illumination. The pots were held on movable tables, 24 per table, and their position and orientation were systematically changed daily to eliminate uneven lighting.

LATERITIC SOILS ON BANDIRIPPUWA ESTATE

General Description of Soil Types

These soils were selected as typical of a very large area in Ceylon and possibly the parent material from which other important soil types have been derived. For the purposes of this investigation three major variants have been recognised and are described.

1. **Lateritic Gravel**. This is a typical laterite which is characteristic of low ridges in the South-west corner of Ceylon. The soils are essentially gravels, overlying or derived from a type of rock (Cabook) which may be quarried and is used for bricks. The "Soil", as such seldom exceeds three feet in depth and there is no obvious stratification but a gradual breakdown into separate components (gravel, sand, silt and clay) as an intimate mixture in the surface layer.

Under natural conditions, e.g., in native forests, there is normally a layer of sandy loam 8 to 9 inches deep above this soil but with clearing and the cultivation of commercial crops there has been considerable erosion and complete removal of what was the original surface soil. Moreover under the continuing influence of climate and vegetation the exposed sub-soil tends to break down and form a new surface soil which is itself erodible, and transportation would therefore appear to be a continuing process.

2. **Lateritic Loam.** Below the ridges and with improved moisture status these lateritic gravels are further decomposed and subject to leaching with formation of a typical kaolinitic white clay layer, of varying and often considerable depth. Over and above this soil there is frequently a superimposed layer of grey loamy sand which may be one to four feet deep and which had obviously been transported from adjacent ridges. It is, in effect, an accumulation of the original surface soil from lateritic ridges.

3. **Lateritic Sands.** On the valley floors, or in flat open country and under the influence of freely moving water silt and clay fractions have been largely transported and the soil is essentially a grey-white

sand overlying kaolinitic clay at a depth of approximately six feet. The original lateritic gravel has almost completely disappeared and may be represented only by brown and yellow mottling in the clay. Here again there is no definite stratification and no hard-pan. The surface sand is loose and friable but the deeper sands are frequently compressed and partially cemented (2).

The present status and location of these soils, as envisaged by the authors, are shown diagrammatically in Fig. 1.

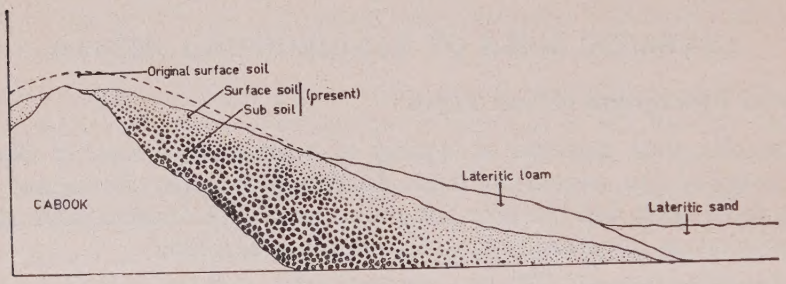


Fig. 1—Diagrammatic representation of the status and location of lateritic soils on Bandirippuwa Estate.

STUDIES ON THE LATERITIC GRAVEL

Experiment 1.

(*a*) **Objective.** To study the effect of selected nutrients on the growth of Plants in lateritic gravel soil.

(*b*) **Design and Procedure.** This was a 2^7 factorial experiment using two species (*Paspalum Commersonii and Phaseolus lathyroides*) and the following six nutrients :—K, P, N, X (a mixture of Mg, Mn, Zn and Fe) Cu and Mo. All pots received a basal dressing of boron. See Table I.

TABLE 1. Forms and Rates of Fertilizer Application in Experiment 3

Designation	Chemical	Rate of Application/Acre
K ..	K_2SO_4	1·5 cwt. = 75 lb. K + 35 lb. S
P ..	$NaH_2PO_4.2H_2O$	3 ,, = 67 lb. P + 49 lb. Na
N ..	$(NH_4)_2SO_4$	5 ,, = 118 lb. N + 135 lb. S
Mg ..	$MgSO_4.7H_2O$	0·5 ,, = 6 lb. Mg + 7 lb. S
Zn ..	$ZnSO_4.7H_2O$	7 lb. = 1·5 lb. Zn + 0·8 lb. S
Mn ..	$MnSO_4.4H_2O$	14 lb. = 3·5 lb. Mn + 2·0 lb. S
Fe ..	$FeSO_4.7H_2O$	14 lb. = 2·8 lb. Fe + 1·6 lb. S
Cu ..	$CuSO_4.5H_2O$	7 lb. = 1·8 lb. Cu + 0·9 lb. S
Mo ..	$(NH_4)_6Mo_7O_{24}.4H_2O$	1·4lb. = 0·5 lb. Mo + 0·7 lb. N
B ..	$Na_2B_4O_7.10H_2O$	4·4lb. = 0·5 lb. B + 0·5 lb. N

The *Paspalum* was planted on 22.3.56, and harvested 3 times, viz., on 12.5.56, 18.6.56 and 6.8.56. The *Phaseolus* was planted on 19.3.56 and harvested twice, viz., on 18.6.56 and 26.7.56. After each harvest the dose of any nutrient which was effective and therefore likely to be in short supply, was increased as follows :—

On 2.5.56—3 cwt./acre $NaH_2PO_4 2H_2O$ was applied to all pots with added phosphate. Total dose now ≡ 133·6 lb./acre of P.

On 16.6.56—7 lb./acre $CuSO_4 \cdot 5H_2O$ was applied to all pots with added copper. Total dose ≡ 3·6 lb./acre of Cu.

On 20.6.56—5 cwt./acre $(NH_4)_2SO_4$ was applied to all pots with added Nitrogen, and 1·5 cwt./acre $MgSO_4 . 7H_2O$ was applied to all pots with added magnesium.
Total dose now ≡ 237 lb./acre of N. & 23·6 lb./acre of Mg.

(*c*) **Results.** Yields were recorded in terms of the dry weight of material harvested at a uniform height. Copper and Molybdenum had no significant effect and the data from four treatments (nil, Cu, Mo, and CuMo) were therefore combined and analysed to test the effect of other nutrients. Mean yields and effective treatments are recorded in Table II.

TABLE II—Experiment 1—Showing Mean Yields and Level of Significance for all Treatments affecting the Yield of two Species in Consecutive Harvests

Species	Harvest	Treatment	Nil	N	P	NP	Effective Treatment	Level of Significance %
P C	(1) Age 44	nil	0·49	·64	2·12	5·04	N	·1
A O	days	nil K	·50	·78	2·59	4·85	P	·1
S M		nil	·72	1·18	2·99	4·58	NP	1·0
P M		X K	·68	1·07	2·89	4·42		
A E	(2) Age 81	nil	4·94	8·33	1·69	8·30	N	·1
L R	days	nil K	5·97	11·22	2·01	13·03	K	1·0
U S		nil	5·02	9·51	1·32	9·16	NP	1·0
M O		X K	5·72	11·34	1·54	15·60	NK	5·0
N	(3) Age 132	nil	1·23	3·79	1·35	1·83	N	·1
I	days	nil K	1·31	9·64	1·45	12·70	P	5·0
							K	1·0
		nil	1·13	4·29	1·52	1·46	NK	1·0
I		X K	1·34	8·62	1·53	13·77	NPK	5·0
P L	(1) Age 60	nil	3·07	4·12	4·47	5·58	N	1·0
H A	days	nil K	2·75	3·59	3·58	4·35	P	1·0
A T								
S H		nil	3·14	4·78	4·68	5·88	X	5·0
E Y		X K	3·52	4·63	4·53	4·68		
O R	(2) Age 99	nil	3·76	5·64	8·58	6·75	P	1·0
L O	days	nil K	5·35	8·48	9·83	10·16		
U I							K	1·0
S D		nil	3·96	5·67	6·21	6·75		
E		K	5·41	8·14	12·32	10·28	PN	5·0
S								

At first glance these results are somewhat confusing because the data from successive harvests do not conform to any one pattern. However the position is clarified in Fig. 2 wherein mean yields for all effective treatments are shown as a series of histograms. Here (as in later experiments) the pattern of responses has changed from one harvest to the next and this can be related to progressive changes in the nutrient status of this soil. The data can be summarized as follows :—

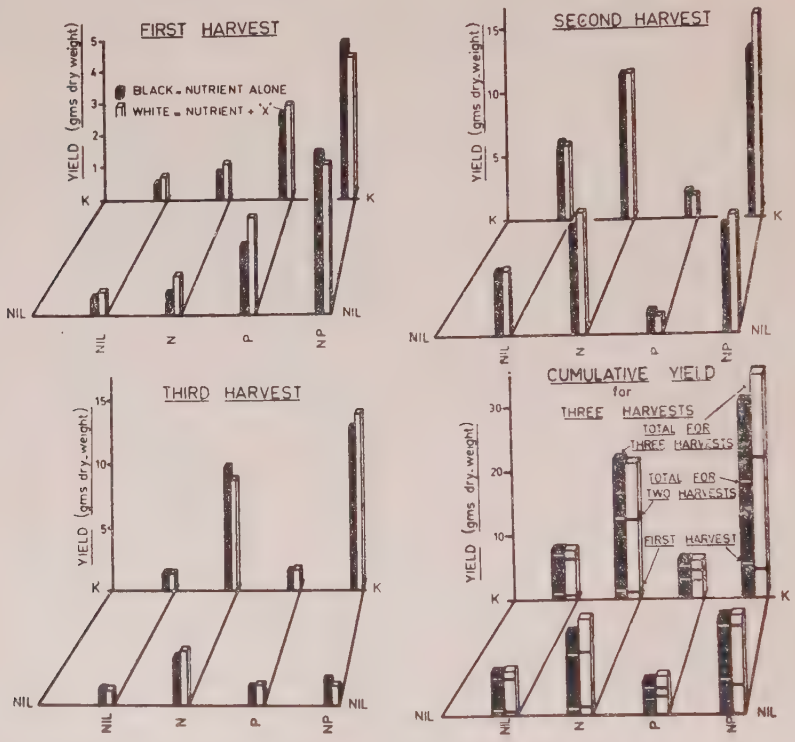


Fig. 2—*Experiment 1.* Showing mean yields for all effective treatments in successive harvests of *Paspalum commersonii.*

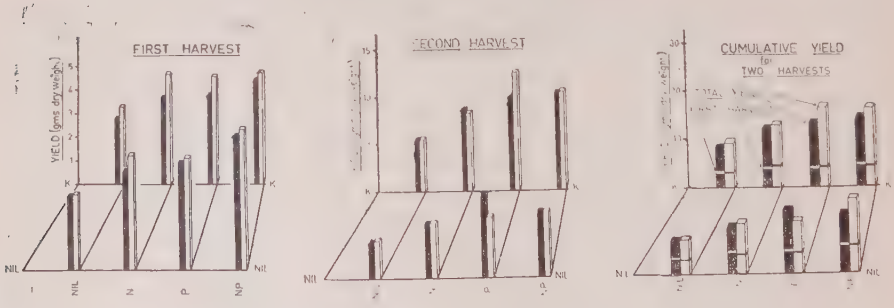


Fig. 3.—*Experiment 1*—Showing mean yields for all effective treatments in successive harvests of *Phaseolus lathyroides.*

1. *Paspalum Commersonii.—First Harvest.* The data show that during the early stages of growth—i.e., prior to the first harvest—there was a very marked response to phosphate (400 per cent. increase in yield) and a still larger response to P and N in combination (900 per cent. increase in yield). Nitrogen alone had no effect and K had no effect either alone or in combination with other nutrients.

"X" had only a small effect, ranging from + 58 per cent. in presence of N to—9 per cent. in presence of NP; giving a significant interaction (NPX) at the 5 per cent. level.

Second Harvest. Data for the second harvest present a somewhat different picture in that there is now a negative response (i.e., a depression in yield) from P alone. Nitrogen alone gave nearly 100 per cent. increase in yield, and the two together (PN) a similar increment, not exceeding 113 per cent.

K, alone or in combination with P, had no effect, but K in combination with N and NP gave increments of 18 and 64 per cent. respectively. There was no significant response to "X".

Third Harvest. Data for the third harvest show an even greater change, with K now having a major effect on the yield of this species. Nitrogen alone gave an increase of nearly 250 per cent.; NK an increase of approximately 675 per cent.; and N. P. K. an increase of over 1,000 per cent.

K and P, alone or in combination, had no significant effect. N. P gave only a small increase of less than 40 per cent. "X" had no significant effect.

2. *Phaseolus lathyroides.* Under favourable conditions most legumes can, and do, obtain appreciable quantities of nitrogen from symbiotic bacteria that are responsible for the development of nodules on their roots. It follows that the direct effect of nutrients is complicated by their effect on these bacteria. Moreover in this experiment it is to be noted that plants of *Phaseolus lathyroides* were harvested some days later than corresponding plants of the grass, *Paspalum commersonii.*

First Harvest. During early growth plants of *Phaseolus* were affected by the several nutrients in much the same way as plants of *Paspalum,* but at a later stage those in all "nil" treatments made relatively vigorous growth and the data for this harvest show relatively small effects from N, P and K.

There was, for instance, relatively a small response to P (intermediate between that for the first and second harvests of *Paspalum*) and an equally small response to N (+ 44 per cent.) and N.P. (+ 85 per cent.). There was no significant response to K.

On the other hand, there was a significant response to 'X'; ranging from + 28 per cent. in presence of K. through 29 per cent. for N.K, and 26 per cent. for P.K, to 8 per cent. for N.P.K.

Second Harvest. In the second harvest there was an appreciable response to P. (+ 91 per cent.) to N (+ 46 per cent.) and to N.P. (+ 74 per cent.). However these would be affected by the activity of symbiotic bacteria and might be more correctly stated as follows :—

P	=	Symbiotic Nitrogen + P	(91 per cent.)
N	=	Artificial Nitrogen	(46 per cent.)
NP	=	Symbiotic N (depressed by artificial N) + P	(74 per cent.)

There was an appreciable response to K, ranging from + 39 per cent. for K alone (K.N.), to a mean value of +175 per cent. for K.P. (= KPN) and K.P.N.

There was no significant response to 'X'.

The progressive effect of individual nutrients may be summarized as follows :—

1. *Phosphates.* Initially (i.e., prior to the first harvest) there was a very big response to phosphate and in the presence of N, this nutrient gave about 400 per cent increase in the yield of *Paspalum.* In later harvests, however, phosphate had only a small effect.

2. *Nitrogen.* Proved to be essential at all stages of growth and with the grass (*Paspalum commersonii*), there was a steadily increasing response to this element, leading to complete control in the third harvest, when no other nutrient was effective in the absence of N.

With the legume (*Phaseolus lathyroides*) there was a smaller response to Nitrogen in the first harvest, and thereafter N had no effect on yield. This would follow naturally from effective nodulation, and fixation of atmospheric nitrogen by symbiotic bacteria.

3. *Nitrogen and Phosphate.* It is of particular interest that in the first *Paspalum* harvest Nitrogen was quite ineffective in the absence of P, whereas in later harvests N alone had a very big effect. On this evidence we must assume that available phosphate, which was originally in very short supply, had increased ; possibly as a result of chemical or biological changes in the soil. The evidence of such change in phosphate status seems incontrovertible, but a full and satisfactory explanation is beyond the scope of this investigation.

4. *Potash.* Initially the addition of Potash (K) had no appreciable effect on yield, and in the second harvest it had only a very small effect, but in the third harvest there was a very big effect with K responsible for more than 25 per cent. of the maximum yield.

5. '*X*' (*Mg + Mn + Zn + Fe*). Throughout all harvests 'X' had only a very small and varying effect, and that only in the absence of one or more major nutrients. In the presence of N.P. & K, its effect was negligible.

These changes in nutrient response are fully supported by the data from subsequent experiments. They are illustrated in Fig. 5.

Experiment 2

(*a*) **Objective.** To study the effect of calcium and magnesium on the response to selected nutrients.

(*b*) **Design and Procedure.** This was a 2^7 factorial experiment using two species (*Paspalum commersonii* and *Phaseolus lathyroides*) and the following nutrients :—K, Ca, Mg, "A" (a mixture of Cu, Zn, and Mn), Fe and Mo.

All pots received a basal dressing of nitrogen, phosphate and boron. Calcium was applied as $CaCC_3$ 10 cwt./acre ($\equiv$ 4 cwt./acre of Ca) mixed in the top two inches of soil. All other nutrients were applied in forms and doses enumerated for Experiment 1 (see Table 1). Both species were planted on June 11, 1956, and both were harvested three times : the *Paspalum* on July 18, 1956, August 21, 1956, and September 24, 1956, the *Phaseolus* on July 28, 1956, August 31, 1956, and September 24, 1956. Extra nutrients were applied as follows:—

On 9.8.56 .. 5 cwt./acre $(NH_4)_2SO_4$ was applied to all pots.
Total dose now $\equiv$ 236 lb./acre of N.

On 9.8.56 .. 3 cwt./acre $NaH_2PO_4.2H_2O$ was applied to all *Paspalum* pots.

On 21.8.56 .. 3 cwt./acre $NaH_2PO_4.2H_2O$ was applied to all *Phaseolus* pots.
Total doses now $\equiv$ 134 lb./acre of P.

On 10.8.56 .. 4·4 lb./acre $Na_2B_4O_7 \cdot 10H_2O$ was added to all pots.
Total dose now $\equiv$ 1 lb./acre of B.

On 27.8.56 .. 1·5 cwt./acre K_2SO_4 was applied to all pots with added K.
Total dose now $\equiv$ 150 lb./acre of K.

(*c*) **Results.** Yields were recorded in terms of the dry weight of material harvested at uniform height. Four nutrients K, Ca, Mg and 'A' had significant effect on yields. Also in the first harvest of *Phaseolus* there was a small, but significant, depression from Fe and Mo, and a number of minor interactions between Mo, Ca and Mg and between Fe, Ca and Mg. However those interactions were all negative, they were not apparent in any complete analysis (2^7 factorial including all data for two species) and with one exception (CaMo) they did not appear in subsequent harvest. The data for four replicates (nil, Fe, Mo and FeMo) were therefore combined and analysed to test the effect of other nutrients. Mean yields and effective treatments are recorded in Table III.

TABLE III—Experiment 2—Showing mean Yields and Level of Significance for all Treatments affecting the Yields of two Species in Consecutive Harvests

Species	Harvest	Treatment	Nil	Ca	Mg	CaMg	Effective Treatments	Level of Significance %
PASPALUM COMMERSONII	(1) Age 37 days	nil	6·23	4·36	5·50	5·18		
		nil K	7·15	4·44	7·52	4·53	K	5·0
							Ca	·1
		nil	5·89	3·84	5·41	3·32		
		A K	6·06	5·03	6·18	4·91		
	(2) Age 71 days	nil	3·09	3·27	3·01	4·11	K	·1
		nil K	3·79	4·04	3·69	4·72	Ca	1·0
							Mg	5·0
		nil	3·38	3·38	3·44	4·27	A	1·0
		A K	4·91	4·40	4·35	4·82	CaMg	1·0
							CaA	5·0
	(3) Age 105 days	nil	·75	·76	·57	·80		
		nil K	4·47	4·61	3·66	5·01		
							K	·1
		A nil	·88	1·22	·84	1·29		
		K	4·20	3·90	5·10	3·85		
PLHATSHEYORLOUISDES	(1) Age 47 days	nil	7·67	7·33	7·68	6·83	K	5·0
		nil K	8·74	7·27	8·19	9·08		
							Mg	5·0
		A nil	7·44	7·48	6·27	5·20	A.Mg.	5·0
		K	10·01	8·94	7·42	6·37		
	(2) Age 81 days	nil	3·34	3·54	2·67	4·30		
		nil K	4·58	5·77	5·09	10·95		
							K	1·0
		A nil	3·55	4·77	3·98	4·57	Ca	1·0
		K	5·83	9·21	6·28	9·01		
	(3) Age 105 days	nil	·68	·79	·72	·71	K	·1
		nil K	1·37	1·64	1·31	2·27		
							Ca	5·0
		A nil	·65	·75	·53	·41	K.Ca	5·0
		K	1·35	2·28	1·39	1·82		

These data may be summarized as follows :—

1. *Paspalum commersonii.* In the first harvest only two nutrients K and Ca had a significant effect on yield. K alone gave an increase of only 9 per cent. and Ca depressed all yields by approximately 30 per cent.

In the second harvest all four nutrients had an effect and there were significant interactions, between Ca and Mg, and between Ca and 'A' K alone increased yields by 34 per cent. Ca had no significant effect, except in the presence of Mg (overall increase of 24 per cent). 'A' had no significant effect except in the absence of Ca (increase of 26 per cent).

In the third harvest only K had an effect. It increased yields by over 400 per cent.

2. *Phaseolus lathyroides.* As with *Paspalum commersonii*, K had only a small effect on yields in the first harvest (increase of 24 per cent.). There was also a negative interaction between 'A' and Mg. Neither 'A' nor Mg alone had any significant effect but together ('A' Mg) they were then responsible for an 18 per cent. depression in yield.

In the second harvest both K and Ca were responsible for comparatively large increments (85 and 48 per cent. respectively), and in the third harvest there was a still further increase from these two in combination. Relative yields for nil, K, Ca, and K Ca, were 100 : 220 : 103 : 310.

In this experiment 'A' (a mixture of Cu, Zn, and Mn) appears to have had no consistent, or beneficial effect. The response to other nutrients (K, Ca, and Mg) is shown diagramatically in Fig. 4 and may be summarized as follows :—

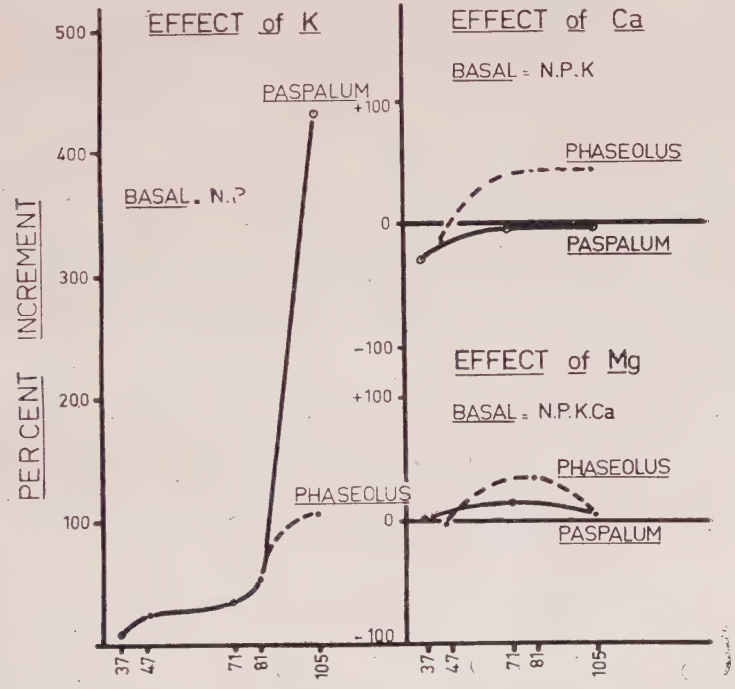


Fig. 4.—*Experiment 2*—Showing the response to K, Ca and Mg in successive harvests of two species (yields relative to that for plants receiving no nutrients).

1. *Potash.* In all three harvests, and with both species, K had an important and progressive effect, and in the third harvest yields of *Paspalum* were increased by more than 400 per cent. However, in this

experiment there was a marked difference between species, with a lesser response to K from the legume *Phaseolus*. That difference was less pronounced in presence of Ca, and in the third harvest K Ca increased the yield of *Phaseolus* by more than 200 per cent.

2. *Calcium.* In the early stages of growth there was a definite depression in yield due to Ca (confirmed in subsequent experiments), but thereafter yields rose steadily and in the second and third harvests yields of *Phaseolus* were increased by approximately 42 per cent. At this rate of application (≡ 4 cwt./acre of Ca) there was no apparent deficiency of Calcium.

3. *Magnesium.* In both experiments Mg ('X' in experiment 1), had only a small and somewhat confusing effect. In some cases—notably in the absence of one or more major nutrients it proved beneficial, but in other combinations Mg had no effect, or it was responsible for some depression in yield. In this experiment increments derived from Mg in the second harvest were not maintained (See Fig. 6) and that in itself suggests that there may have been some other deficiency which was affecting the response to Magnesium.

Experiment 3

(*a*) **Objective.** To measure the effect of N and P in presence of Ca, and to separate any effects of Cu, Zn, and Mn in 'A' of experiment 2.

(*b*) **Design and Procedure.** This was a 2^6 factorial experiment, using two species (*Paspalum commersonii* and *Phaseolus lathyroides*), and the following five nutrients:—N, P, Cu, Zn, and Mn. All pots received a basal dressing of Potash, Calcium, Magnesium, Iron, Molybdenum and Boron. Calcium was applied as in experiment 2; Copper was applied as $CuSO_4 . 5H_2O$ at 21 lb./acre (≡ 5.4 lb. Cu). All other nutrients were applied in forms and doses enumerated for Experiment 1 (See Table 1).

Both species were planted on June 11, 1956, and harvested simultaneously on three occasions, viz., July 30, 1956, September 3, 1956, and October 15, 1956. Extra nutrients were applied on the following dates:—

10.8.56—3 lb./acre $Na_2B_4O_7 . 10H_2O$ was applied to all pots. Total dose now ≡ 1·0 lb. of B.

12.8.56—1·5, cwt./acre K_2SO_4 + 56 lb./acre $MgSO_4 \cdot 7H_2O$ 3 lb./acre $Na_2B_4O_7 . 10H_2O$ were added to all pots.
Total dose now ≡ 150 lb. of K, 11·8 lb. of Mg, and 1·5 lb. B/acre.

16.8.56—5 cwt./acre $(NH_4)_2SO_4$ and 3 cwt./acre $Na\,H_2PO_4 . 2H_2O$ were applied to pots with added N or P.
Total dose now ≡ 237 lb. /acre of N, and 134 lb./acre of P.

17.9.56—1.5 cwt./acre of K_2SO_4 was applied to all pots. Total dose now ≡ 225 lb./acre of K.

25.9.56—5 cwt./acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose now ≡ 355 lb./acre of N.

(*c*) **Results.** The data from this experiment were in all respects similar to those recorded for experiment 1, with N and P the only nutrients having a real and consistent effect on yield. Manganese had no significant effect in any harvest, or on either species, and mean yields for two replicates (nil and Mn) were calculated and analysed to test the effect of other nutrients. Mean yields and effective treatments are shown in Table IV.

TABLE IV—Experiment 3—Showing Mean Yields and Effective Treatments in Consecutive Harvests of two Species

Species	Harvest	Treatment	Nil	N	P	NP	Effective Treatments	Level of Significance %
PACAS MAL UMNII	(1) Age 49 days	nil	3·52	7·54	4·80	16·78	N	·1
		nil Zn	5·87	8·46	5·25	13·36	P	·1
							NP	1·0
		nil	3·70	8·28	5·51	16·11	Zn N	5·0
		Cu Zn	4·71	8·50	6·52	13·72	Zn P	5·0
	(2) Age 84 days	nil	1·44	5·19	1·40	6·38	N	·1
		nil Zn	1·08	4·84	1·31	6·24	P	1·0
		nil	1·18	4·70	1·21	7·47	NP	1·0
		Cu Zn	1·14	5·02	1·47	6·78		
	(3) Age 126 days	nil	1·04	4·12	1·12	4·51	N	·1
		nil Zn	·80	3·38	1·23	5·82		
							P	1·0
		nil	·99	3·62	1·14	6·51	NP	5·0
		Cu Zn	·98	3·97	1·20	6·21		
PHASEOLUS LATHYROIDES	(1) Age 49 days	nil	4·47	5·77	7·09	10·27	N	1·0
		nil Zn	5·73	6·01	7·99	11·70		
							P	·1
		nil	5·73	5·77	5·80	8·34		
		Cu Zn	4·11	7·06	7·12	11·04	NP	5·0
	(2) Age 84 days	nil	1·33	1·44	3·38	2·72		
		Nil Zn	1·44	1·55	2·63	3·73		
							P	·1
		nil	1·21	1·82	2·64	2·66		
		Cu Zn	1·03	1·58	2·21	2·34		
	(3) Age 126 days	nil	1·25	·74	3·83	1·17		
		nil Zn	·93	1·02	·76	2·37		
							P	5·0
		Cu nil	·31	·60	·94	2·78		
		Zn	·24	1·62	·83	1·94		

As in the two previous experiments major effects were all derived from applications of N and P. Copper had no effect, and the only significant response to Zn was in the first harvest of *Paspalum*. In that harvest there were negative interactions between Zn and N, and between Zn and P. In the absence of P or N, Zn increased mean yields by 20 and 27 per cent. ; in presence of P or N, mean yields were decreased by the same amounts.

The data for two treatments (N and P) are summarized in Table V.

TABLE V—Experiment 3—Showing relative Yields for four Treatments in Consecutive Harvests of two Species

Species	Harvest	Nil	N	P	NP
PASPALUM ..	1	100	184	124	337
	2	100	408	111	553
	3	100	396	131	605
PHASEOLUS ..	1	100	122	139	260
	2	100	128	216	228
	3	100	153	229	316

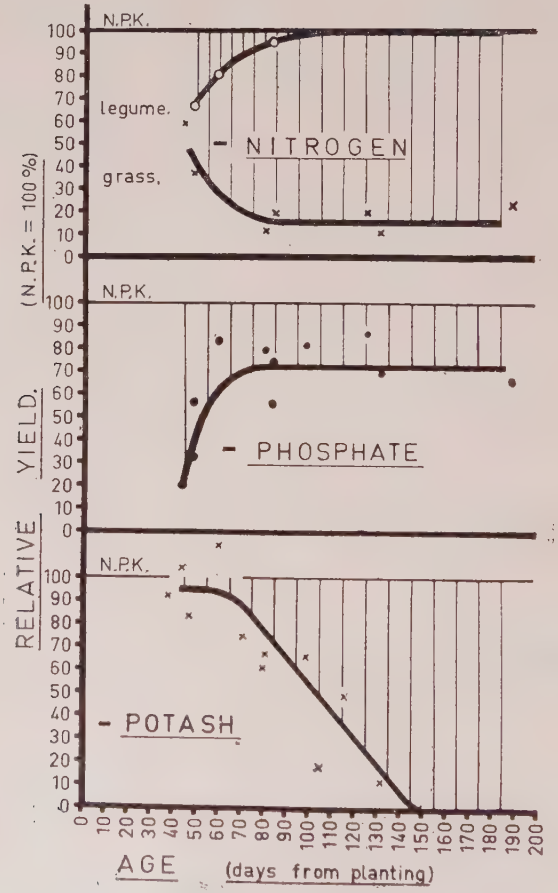


Fig. 5.—Diagram compounded from three experiments (Nos. 1, 2 and 3) showing progressive effects from absence of N P and K.

(This diagram incorporates all relevant data from these three experiments with the exception of one reading that was known to be a-typical (" P " for the 3rd harvest on *Phaseolus* in Exp. 3 :—Plants affected by virus). In experiment

2, only the data from one replicate (Ca and Mg) were used. Data for a 4th harvest in Exps. 2 and 3 were from continued growth in relevant treatments—other treatments being discontinued.)

(*d*) **Discussion on Experiments 1, 2, and 3.** Data from these three experiments have been combined in Fig. 5, wherein the yield from all plants receiving N, P, and K is recorded at 100 per cent. and the effect of any deficiency in terms of a "relative yield" representing the lesser growth in absence of that particular nutrient. For example, in the absence of phosphate relative yields rose steadily from a mean value of 20 at 45 days, to a mean and consistent value of approximately 70 after 80 days.

In the absence of nitrogen, relative yields of *Paspalum commersonii* decreased steadily to a consistent value of 16 ; whereas relative yields for *Phaseolus lathyroides* rose steadily to a value of 100, indicating effective nodulation of the legume.

It is of particular interest that in this diagram there is a marked difference in the shape of curves for "— P" and "— N" on the one hand, and that for "— K" on the other. In the former cases relative yields tended towards an asymptote representing the final level of production where a given nutrient is in short supply. (i.e., the normal expectation for any limiting factor), but in the latter case relative yields decreased steadily to zero, and it should be noted that at an age of 150 days (4th harvest for experiment 2) between 50 and 75 per cent. of these plants were dead. A curve of that shape is quite unusual, and it suggests that there had been an active removal, or fixation, of available K.

This effect from potash deficiency—including the death of plants—has now been recorded in a number of experiments with these lateritic soils, and in later experiments both soil and plants have been analysed in order to gain some further information on Potash status.

A bulk sample, including all tissues above a height of one inch, in healthy plants of *Paspalum commersonii* (i.e., those from K + treatments), contained 2.71 per cent. of K_2O. In Experiment 2, where the mean cumulative yield from Ko pots did not exceed 9.35 gms., this would be equivalent to 0.210 gms. elemental K per pot. The soil, as used in these experiments, contained 240 p.p.m. of K_2O * approximately 0.355 gms. elemental K for any pot with 2,000 gms. of soil. Even allowing a suitable margin for the potash content of roots, these figures suggest that potentially available K in this soil would be sufficient to meet all requirements for plant growth.

* Analysis based on HCl extraction for 1 hour and volumetric determination of cobaltinitrite (Milne J.A.S. 1929).

On the other hand there was visual evidence of potash deficiency, and plants of *Paspalum commersonii* from Ko pots contained as little as 0.87 per cent. K_2O. Since our basic technique precluded any possibility of leaching, some form of K-fixation would appear to be the only logical explanation of these low yields, and the death of plants.

The soil used for these experiments was collected in the field and air-dried, for convenience of storage in large wooden bins. It was then transferred to pots and raised to 85 per cent. field capacity with distilled water. Initially there was no evidence of potash deficiency, but in course of some 18-20 weeks acute symptoms were recorded. This suggested that air-drying and disturbance of the soil may have caused some release of normally unavailable K, and that repeated drying and aeration of the soil in Ko pots might have the same effect again.

Accordingly a number of Ko pots from experiments wherein the majority of plants had died, were emptied and the soils aerated and air-dried for periods of two weeks. Those experiments have not been completed, but relative yields of 100 and 80 for K + and Ko pots have been recorded in the first harvest.

At this juncture, the amount of K-fixation could not be assessed, and no opinion can be advanced regarding the mechanism of fixation.

In all three of these experiments and during the third harvest, the majority of plants made relatively slow growth and they showed a characteristic discoloration and necrosis which could not be related to presence or absence of any nutrient.

In Experiment 1, and on visual symptoms, this was attributed to a deficiency of calcium, but in Experiment 2, the same symptoms appeared irrespective of the presence or absence of Ca, and they were again apparent in Experiment 3.

In Experiment 3, all plants of *Paspalum*, irrespective of treatment, were rated according to the intensity of these symptoms, and those ratings compared with recorded *p*H for individual pots. There was a significant but false correlation (—0.5399) (co-efficient for error not significant) and it appeared that both were related to some other factor. Both ratings and *p*H were then compared with the cumulative yields for all major treatments. The correlations between 'yield' and 'symptoms' (+0.8790), and between 'yield' and '*p*H' (—0.7108) were both significant. However by using partial correlations it was shown that the correlation between 'symptoms' and 'yield' with constant *p*H was highly significant (+0.8363) ; and *p*H, with constant yield, was not significant (—0.2505).

In other words, the data showed that these symptoms were positively correlated with the cumulative yield from individual treatments, and that any change in soil pH was purely incidental.

An hypothesis that these symptoms might follow from some accumulation of toxic substance was discounted by two subsequent experiments (experiments 4 and 5), and with elimination of these two hypotheses it seemed that the observed symptoms must be related to some further deficiency, or to the amount of effective fertilizer applied.

In Experiment 2, there was one apparent anomaly in the third harvest, where the response to K was greater in the case of *Paspalum*, a grass, than with *Phaseolus*, a legume (see Fig. 4), and this might be interpreted in terms of a sub-optimal amount of K. Again, in that experiment, the decreasing response to Mg in the third harvest might be interpreted as a further consequence of such deficiency.

Unfortunately at this juncture all plants of *Phaseolus* were affected by a virus and they had to be discarded. They were therefore uprooted and all of the *Phaseolus* pots from Experiments 2 and 3 were re-planted with seed of *Paspalum commersonii*. Those pots were used in Experiments 5 and 6.

Experiment 4

(*a*) **Objective.** 1. To determine the effect of leaching (i.e. removal of any soluble, toxic substances that may have accumulated in the soil after three harvests of *Paspalum commersonii*). 2. To measure the effect of additional K on the yield of young and old plants, and on any response to Ca and Mg.

(*b*) **Design and Procedure.** For this experiment the original pots and treatments in Experiment 2 were maintained, and the following modifications were introduced:—(1) All pots previously given Mo were leached, and (2) all plants in pots previously given Fe were uprooted and the pots replanted with seed of the same grass. Only pots that had grown *Paspalum* in Experiment 2 were used.

The 'leached' pots were pierced to allow free drainage and subsequently over-watered at frequent intervals for three successive days. The pots were then re-sealed. Twenty-six litres of leachate were collected and used for Experiment 5. A sample from that leachate was analysed and found to contain the following nutrients:—

Total solubles ·071 gm./100 m.l. ≡ 413 lb./acre	From 32 Pots
N (as NO_3) 10 parts per million ≡ 4·00 lb./acre	
N (as NH_3) 0·15 parts per million ≡ ·08 lb./acre	
K (as K_2O) minute trace ..	
P (as P_2O_5) ·0001 gm/100 m.l. ≡ ·56 lb./acre	
Ca (as CaO) ·0105 gm./100 m. l. ≡ 122·26 lb./acre	

Plants that were uprooted were withdrawn with the least possible disturbance of the soil, and only the larger roots were taken. The pots were re-sown after leaching, when the soil was "cultivated", to a depth of half an inch.

Following this preparation, and on September 25,1956, the original plants were cut back to a height of one inch, and at the same time the dosage of K was increased to $4\frac{1}{2}$ cwt./acre K_2SO_4. On October 9, 1956, 5 cwt/acre of $(NH_4)_2SO_4$ was applied to all pots. The modified experiment was then continued as a 2^5 factorial with the following treatments :—

(1) nil
(2) $K4\frac{1}{2}$ ≡ 225 lb./acre of K
(3) Ca10 ≡ 4 cwt./acre of Ca
(4) Mg_{56} ≡ 5·9 lb./acre of Mg
(5) "A" ≡ 1·8 lb./acre of Cu ; 1·5 lb./acre of Zn ; and 3·5 lb./acre of Mn
(6) Leached.
(7) Re-planted.

(*c*) **Results.** The *Paspalum* was harvested on November 7, 1956. There were no significant differences due to Mg. Mean yields for two replicates (nil and Mg), and effective treatments are shown in Table VI.

TABLE VI—Experiment 4.—Showing Mean Yields and Level of Significance for all Treatments affecting the Yield of Paspalum commersonii

Treatment	New Plants		Old Plants		Effective Treatments	Level of Significance %
	Leached	—	Leached	—		
Nil Nil Nil ..	·21	·27	0	·03	K	·1
K Nil Nil ..	·74	1·97	6·32	2·26	Ca	1·0
Nil Ca Nil ..	·11	·18	0	0	Age	·1
K Ca Nil ..	2·39	3·39	7·70	9·13	KCa	1·0
Nil Nil A ..	·12	·19	·07	·04	K. Age	·1
K Nil A ..	1·31	1·19	4·52	3·39		
Nil Ca A ..	·20	·20	0	·37		
K Ca A ..	1·37	2·28	7·14	6·65		

There was no effect from leaching.

The data show that there were marked differences in the yield of new and old plants. (The data for old plants (unleached) in this experiment were used in Fig. 5, to denote a fourth harvest from Experiment

2.) All of the new plants made some growth, and mean yields for the nil, K, and KCa treatments were as 1 : 5 : 9. In the absence of K, ten of the sixteen old plants died, and corresponding yields (excluding the ten) were as 1 : 20 : 37. Ca, alone had no effect, but there was a marked response to Ca in combination with K (80 per cent. increase in yield).

These effects are shown diagramatically in Fig. 6 together with the much smaller responses to Mg. The response to Mg was not significant and there were no obvious or consistent trends.

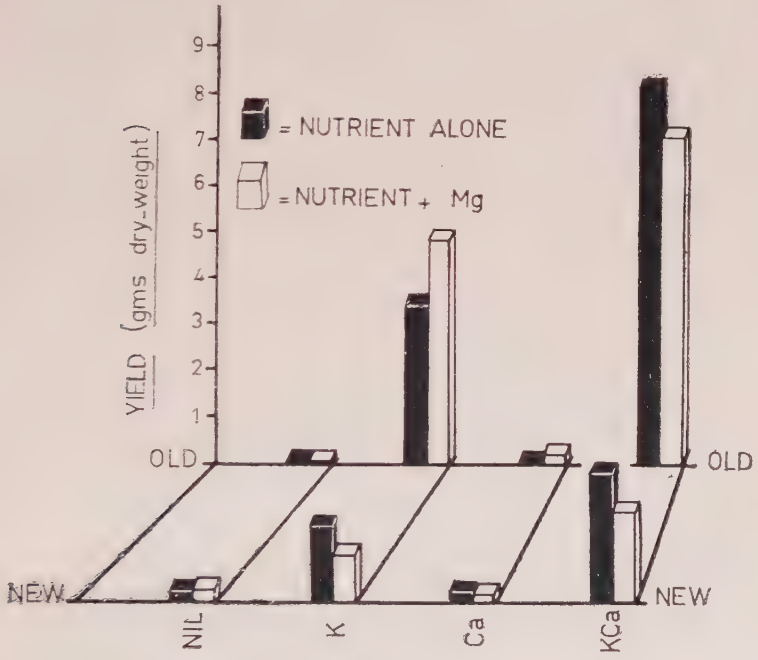


Fig. 6.—*Experiment 5*—Showing mean yields for four treatments in old and new plants of *Paspalum commersonii*.

Experiment 5

(*a*) **Objective.** To ascertain whether leachate (from Experiment 4) would affect the growth of plants.

(*b*) **Design and Procedure.** This experiment was a simple comparison of two treatments (leachate vs. distilled water), using six replicates of each of two soils.

The soils were 'lateritic gravel' and 'cinnamon sand'. Pots containing the lateritic soil were given a basal dressing of N. P. K. and Ca (5 cwt./acre), those containing cinnamon sand a basal dressing of N. P. K., Cu, and Ca (10 cwt./acre). Calcium was applied as CaCO mixed with the top two inches of soil, all other nutrients were applied in forms and doses enumerated for Experiment 1.

Seed of *Paspalum commersonii* was planted on September 23, 1956, using distilled water, and treatments were commenced on September 26, 1956. Additional nutrients were applied as follows :—

On 1.12.56—5 cwt./acre $(NH_4)_2SO_4$, and 3 cwt./acre K_2SO_4 was applied to all pots.
Total dose = 236 lb./acre of N, and 134 lb./acre of P.

All plants were harvested three times, viz., on November 12, 1956, December 17, 1956, and January 11, 1957.

(*c*) **Results.** Cumulative yields from the three harvests are shown in Table VII. [There were no significant differences between treatments.]

TABLE VII—Experiment 5—Showing Cumulative Yields from Three Harvests of Paspalum commersonii

Soil	Treatment	Replicates						Total
		1	2	3	4	5	6	
Gravel	Dist. H_2O	21·90	18·96	18·24	15·79	17·34	18·09	110·32
	Leachate	20·00	17·81	18·15	21·96	16·45	19·15	113·52
Sand	Dist. H_2O	16·97	18·25	18·53	17·34	17·14	16·27	104·50
	Leachate	18·24	17·06	15·86	16·22	18·38	17·36	103·12

Experiment 6

(*a*) **Objective.** To measure the effect of increasing K, and the response to Ca and Mg in presence of increasing K ; on soil previously used to grow *Phaseolus lathyroides.*

(*b*) **Design and Procedure.** This was a $2^{1} \times 5^{1}$ factorial experiment, using only one species (*Paspalum commersonii*) and the following nutrients K, Ca, Mg, and "A" (see Experiment 2). There were five levels of K. The pots and the soil were those previously used in Experiment 2. The original plants of *Phaseolus* were all uprooted with a minimum disturbance of the soil, and the several treatments were compiled from the original (Experiment 2), and subsequent applications, viz :—

Ko	Nil	
K_3	1·5 cwt./acre applied 11.6.56 1·5 cwt./acre applied 27.8.56	K_2SO_4
	Total dose ≡ 150 lb. K, 63 lb. S/acre.	
K $4\frac{1}{2}$	1·5 cwt./acre applied 11.6.56 1·5 cwt./acre applied 27.8.56 1·5 cwt./acre applied 12.10.56	K_2SO_4
	Total dose ≡ 226 lb. K, 93 lb. S/acre.	
K 6	1·5 cwt./acre applied 11.6.56 1·5 cwt./acre applied 27.8.56 1·5 cwt./acre applied 8.10.56 1·5 cwt./acre applied 12.10.56	K_2SO_4
	Total dose ≡ 310 lb. K, 124 lb. S/acre	
K $7\frac{1}{2}$	1·5 cwt./acre applied 11.6.56 1·5 cwt./acre applied 27.8.56 1·5 cwt./acre applied 8 10.56 3 0 cwt./acre applied 12.10.56	K_2SO_4
	Total dose ≡ 376 lb. K, 154 lb. S/acre.	
Mg	56 lb./acre applied 11.6.56 56 lb./acre applied 18.10.56	$MgSO_4 \cdot 7H_2O$
	Total dose ≡ 12 lb. Mg, 14 lb. S/acre	
Ca	10 cwt./acre applied 11.6.56	$CaCO_3$
A	7 lb./acre $CuSO_4.5H_2O$ 7 lb./acre $ZnSO_4.7H_2O$ 14 lb./acre $MnSO_4.4H_2O$	applied 11.6.56

All pots had a basal dressing of nitrogen, phosphate and boron applied for Experiment 2. The experiment was harvested three times, viz., on November 25, 1956, December 29, 1956, and January 24, 1957.

Individual yields and significant effects are recorded in Table VIII.

TABLE VIII—Experiment 5—Showing individual Yields and Significant effects in three successive Harvests of Paspalum commersonii

Harvest	Treatment	nil		Mg		Effective Treatments	Level of significance %
		nil	Ca	nil	Ca		
(1) Age 49 days	Ko	·67	·65	1·49	·96		
	K3	3·29	3·02	2·91	3·97	K (+)	·1
	K4½ Ao	2·65	3·11	2·44	5·08	Ca (+)	·1
	K6	2·64	3·56	3·54	4·68	K. Ca	1·0
	K7½	3·77	2·69	3·62	5·14		
	Ko	·99	·76	·89	·97		
	K3	3·24	3·79	3·29	4·55		
	K4½ A_1	2·68	6·06	1·60	4·60		
	K6	3·01	2·92	2·82	5·19		
	K7½	3·42	4·40	3·20	3·29		
(2) Age 82 days	Ko	1·87	1·47	1·28	·20*		
	K3	5·16	4·07	2·98	4·47		
	K4½ Ao	6·88	9·87	1·44*	7·14	K (+)	·1
	K6	3·63	3·84	4·91	·33*	Ca (+)	1·0
	K7½	2·20	6·75	2·85	7·32	A. Mg	1·0
	Ko	1·04	1·37	·56*	1·24		
	K3	3·32	4·04	5·28	5·93		
	K4½ A_1	3·58	8·24	3·25	7·47		
	K6	2·12	7·55	5·32	7·28		
	K7½	5·07	3·82	8·27	6·91		
(3) Age 108 days	Ko	·60	·76	·43	·45*		
	K3	2·00	2·17	1·23	2·80		
	K4½ Ao	2·42	1·94	·46*	2·20	K	·1
	K6	2·19	2·39	2·43	·96*		
	K7½	·89	2·37	·62	1·53		
	Ko	·45	·49	0 *	·33		
	K3	2·39	2·30	2·15	1·68		
	K4½ A_1	·92	1·91	1·85	1·49		
	K6	·93	2·24	1·12	1·47		
	K7½	1·63	·64	1·59	1·74		

N.B.—Significance at 5% level not recorded.

In all three harvests there was a steady improvement from increasing dosage of K, up to 4½ cwt. acre. There was also a marked response to Ca. Magnesium had no significant overall effect, and it was noticed that whereas in some pots Mg appeared to be beneficial, there were at least four pots in which the plants made very poor growth, and developed symptoms of disease, or toxicity.

These a-typical plants were more frequent in one replicate (Ao) and responsible for a significant interaction (A.Mg) in the second harvest.

Low yields from these a-typical plants tended to confuse the general picture, and in order to clarify the response to K and Ca., relative yields were calculated on the basis of mean values for four replicates (nil), A, (Mg, and A.Mg). See Table IX.

TABLE IX—Experiment 5—Showing relative Yields for Effective Treatments in Successive Harvests of Paspalum commersonii

Harvest	Treatment	Nil	K3	K4½	K6	K7½
(1)	nil	100	315	232	297	346
	Ca	100	461	567	491	466
(2)	nil	100	354	320	338	389
	Ca	100	432	763	443	578
(3)	nil	100	538	392	461	328
	Ca	100	450	376	352	330
Mean	nil	100	402	315	365	354
	Ca	100	448	569	429	458
Mean		100	425	442	397	406

In some cases—notably in the values for Ca in the second harvest,—these data tended to be irregular, but the general pattern of response was clear from overall mean values, and from smoothed curves portrayed in Fig. 7.

In all three harvests there was a steady increase in yields from increasing dosage of K, up to 4½ cwt. K S0 per acre. There was very little, if any improvement from higher doses. In the absence of K, Ca had very little effect on yield, but in presence of K there was a steady improvement culminating in a mean increment of approximately 80 per cent. at K4½. However, that increment was not maintained at higher dosage of K, and there was a steady decrease to approximately 35 per cent. at K7½.

A curve of that shape is generally indicative of some other deficiency (in this case possibly insufficient N or P) and that hypothesis is supported by steadily decreasing increments in successive harvests (i.e., 55, 34, and 17 per cent. at K7½). In that event, we can assume that the amount of Ca applied (10 cwt./acre $CaCO_3$) was sufficient to meet all requirements.

In effect, this Experiment showed that this soil is deficient in both K and Ca. The optimum dosage of K would appear to be approximately 4½ cwt./acre K_2SO_4 (or equivalent), and the lack of any response

to higher dosage suggests that the soil cannot fix more than that amount. Ten cwt./acre of $CaCO_3$, (or equivalent dosage) was apparently sufficient to meet all requirements, and it is possible that a smaller amount could be equally effective.

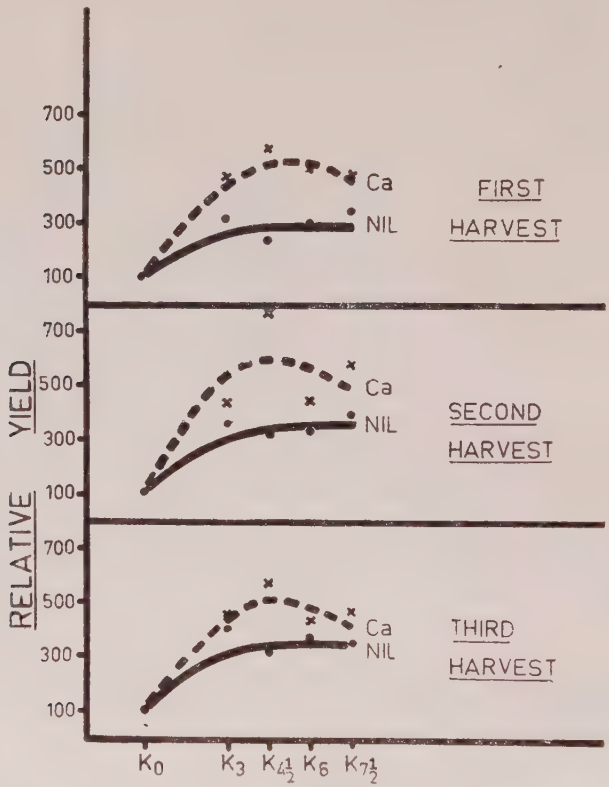


Fig. 7.—*Experiment 6*—Diagram compiled from relative yields to show the general pattern of responses to K and Ca.

Experiment 7

(*a*) **Objective.** To study the effect of heavy applications of K, on plants grown in soil previously used to grow plants of *Phaseolus lathyroides* (See Experiment 3).

(*b*) **Design and Procedure.** This was a $2^3 \times 4^1$ factorial experiment, using one species (*Paspalum commersonii*), three nutrients (N, P, and Cu) and four levels of K. The procedure was in all respects similar to

that recorded for experiment 6. K was applied as K_2SO_4 at rates of $4\frac{1}{2}$, 6, $7\frac{1}{2}$ and $10\frac{1}{2}$ cwt. per acre, compiled from the original and subsequent applications, as follows :—

$K4\frac{1}{2}$	1·5 cwt./acre added 11.6.56 1·5 cwt./acre added 12.8.56 1·5 cwt./acre added 17.9.56	K_2SO_4

Total dose ≡ 226 lb. K, 93 lb. S/acre.

K6	1·5 cwt./acre added 11.6.56 1·5 cwt./acre added 12.8.56 1·5 cwt/acre added 17.9.56 1·5 cwt./acre added 15.10.56	K_2SO_4

Total dose ≡ 301 lb./K, 124 lb. S. per acre.

$K7\frac{1}{2}$	1·5 cwt./acre added 11.6.56 1·5 cwt./acre added 12.8.56 1·5 cwt./acre added 17.9.56 3·0 cwt./acre added 14.10.56	K_2SO_4

Total dose ≡ 376 lb. K, 155 lb. S per acre.

$K10\frac{1}{2}$	1·5 cwt./acre added 11.6.56 1·5 cwt./acre added 12.8.56 1·5 cwt./acre added 17.9.56 6·0 cwt./acre added 15.10.56	K_2SO_4

Total dose ≡ 527 lb. K, 217 lb. S per acre

Nitrogen and phosphate were applied at only one dosage, again compiled from successive applications, viz :—

P	3 cwt./acre $Na\ H_2\ PO_4\ 2H_2O$ added 11.6.56 3 cwt./acre $Na\ H_2PO_4\ 2H_2O$ added 16.8.56

Total dose ≡ 134 lb. P per acre.

N	5 cwt./acre $(NH_4)_2SO_4$ added 11.6.56 5 cwt./acre $(NH_4)_2SO_4$ added 16.8.56 5 cwt./acre $(NH_4)_2SO_4$ added 25.9.56

Total dose ≡ 335 lb. N, 405 lb. S per acre.

Copper was applied at the rate of 21 lb. $CuSO_4,5H_2O$, on June 18, 1956. (≡ 5.4 lb. acre of Cu).

All pots had a basal dressing of calcium, magnesium, iron, molybdenum and boron, applied June 11, 1956 ; in forms and doses described for Experiment 3. Seed of *Paspalum commersonii* was planted on October 15, 1956, and the Experiment was harvested once, on December 17, 1956.

(c) **Results.** Individual yields and effective treatments are recorded in Table X.

TABLE X—Experiment 7—Showing individual Yields, and level of Significance for all treatments affecting the yield of Paspalum commersonii

Treatment	K4½	K6	K7½	K10½	Effective Treatments	Level of significance %
Nil Nil Nil	2.17	1.96	2.12	2.21	N	.1
N nil nil	7.22	6.43	4.52	2.49	P	1.0
nil P nil	3.58	2.59	2.22	2.94	NP	1.0
N P nil	10.65	11.43	11.85	9.49		
nil nil Cu	2.33	1.69	2.65	2.17		
N nil Cu	6.18	4.19	7.89	6.06		
nil P Cu	1.92	1.68	2.35	2.78		
N P Cu	7.86	11.69	11.57	12.70		

There was no effect from increasing dosage of K (i.e., doses above 4½ cwt. K_2SO_4 per acre), and only N and P had an effect on yields. The experiment therefore served only to confirm previous results.

Discussion on Experiments 4, 5, 6, and 7.

These four experiments all used potted soil that had previously grown plants of *Paspalum commersonii* or *Phaseolus lathyroides* for periods up to 185 days (6 months). That soil was used deliberately as a mature sample in which the natural levels of P and K had reached stability. The experiments were designed primarily to study the response to increasing dosage, and the fixation of K. They were also designed to give some information on any response to Ca, Mg and selected minor elements (Cu, Zn, Mn, Fe, and Mo). Two experiments (experiments 4 and 5), were designed to test an hypothesis that the roots of *Paspalum commersonii* might exude some soluble toxic compound which would affect the subsequent growth of plants. Finally, these experiments were jointly designed to determine the cause of deficiency symptoms that were observed in Experiments 1, 2, and 3.

The data from these four experiments were quite consistent, and may be summarized as follows:—

1. *Potassium : Dosage and Fixation.* There was a steady increase in the yield of *Paspalum commersonii* with increasing dosage of K ; up to 4½ cwt. K_2SO_4 per acre. There was very little, if any, increment from higher rates of application, and it would appear that nine inches (depth) of this soil would not fix more than that amount of K.

2. *Calcium.* This soil is deficient in Ca, and increments of 80 per cent. were recorded from applications of 10 cwt. $CaCO_3$ per acre. Under the conditions of these experiments that amount was sufficient to meet all requirements, and it is possible that a smaller dose would be equally effective.

3. *Magnesium.* There was no significant or consistent response to Mg, and this was confirmed by an analysis of relative yields for grouped treatments and individual harvests, in four experiments (Experiment 1, 2, 4, and 6); See Table XI.

TABLE XI—Relative Yields for nil and Mg ("X" in experiment 1) in selected Treatments and individual Harvests, from four Experiments

Experiment	Species	Harvest	Nil	"X"	K	K "X"
(1)	PASPALUM	1	100	114	100	104
		2	100	107	100	106
		3	100	102	100	101
	PHASEOLUS	1	100	107	100	122
		2	100	91	100	107
			nil	Mg	Ca	CaMg
(2)	PASPALUM	1	100	97	100	101
		2	100	95	100	119
		3	100	98	100	96
	PHASEOLUS	1	100	87	100	89
		2	100	104	100	124
		3	100	99	100	104
(4)	PASPALUM	New	100	68	100	70
		Old	100	140	100	88
(6)	PASPALUM	1	100	107	100	152
		2	100	88	100	104
		3	100	68	100	75
	PHASEOLUS	1	100	150	100	115
		2	100	64	100	82
		3	100	106	100	88

Boron had no significant effect on yields, but in the data for *Medicago* there was an apparent trend towards increasing yields with increasing dosage up to B8 (relative yields of 100 : 140 : 225 : 150). However, that trend was not confirmed in *Phaseolus* (relative yields of 100 : 56 : 51 : 58), or in *Paspalum* (100 : 107 : 109 : 100).

The data therefore suggest that there is no deficiency of boron in this soil.

Experiment 9

(*a*) **Objective.** To measure the effect of sulphur on the growth of plants in lateritic gravel soil.

(*b*) **Design and Procedure.** This experiment was a simple comparison of two treatments, " nil " and " Sulphur " ; using three species (*Paspalum commersonii, Medicago sativa* and *Phaseolus lathyroides*). There were twelve formulations, comprising six mixtures containing sulphur and six with no sulphur, viz :—

(1) K_2SO_4 + (NH_4NO_3 + $MgCl_2$ + $CaCO_3$)
(2) $(NH_4)_2SO_4$ + (KCl + $MgCl_2$ + $CaCO_3$)
(3) $MgSO_4$ + (KCl + NH_4NO_3 + $CaCO_3$)
(4) $CaSO_4$ + (KCl + NH_4NO_3 + $MgCl_2$)
(5) H_2SO_4 + (KCl + NH_4NO_3 + $MgCl_2$ + $CaCO_3$)
(6) S_4 + (KCl + NH_4NO_3 + $MgCl_2$ + $CaCO_3$)

and

(7) KCl + (NH_4NO_3 + $MgCl_2$ + $CaCO_3$)
(8) NH_4NO_3 + (KCl + $MgCl_2$ + $CaCO_3$)
(9) $MgCl_2$ + (KCl + NH_4NO_3 + $CaCO_3$)
(10) $CaCO_3$ + (KCl + NH_4NO_3 + $MgCl_2$)
(11) HCl + (KCl + NH_4NO_3 + $MgCl_2$ + $CaCO_3$)
(12) nil + (KCl + NH_4NO_3 + $MgCl_2$ + $CaCO_3$)

All formulations contained the same amount of K, N, Mg, and Ca. The basic treatment was K_2SO_4, 6 cwt/acre 301·2 lb./acre of K, and 123·6 lb./acre of S. All pots received a basal dressing of phosphate (3 cwt./acre $NaH_2PO_4 \cdot 2H_2O$) and boron (13·2 lb/acre $Na_2B_4O_7 \cdot 10H_2O$). The experiment was planted on December 22, 1956 : the *Paspalum* was harvested on February 1, 1957, and the two legumes on February 7, 1957.

(*c*) **Results.** Individual yields and effective treatments are recorded in Table XIII.

TABLE XIII—Experiment 9—Showing individual Yields and Level of Significance for all Treatments affecting the Yield of three Species

Species	Treatment	1/7	2/8	3/9	4/10	5/11	6/12	Effective treatment	Level of significance %
PASPALUM	S	2·83	1·92	2·63	2·44	3·55	2·09	Species	0.1
	nil	·77	2·80	4·27	2·25	3·11	2·89		
MEDICAGO	S	·65	·13	·44	·45	·16	·11		
	nil	·48	·32	·27	·53	·42	·24		
PHASEOLUS	S	3·51	2·98	3·23	2·87	2·93	3·57		
	nil	3·46	2·94	4·33	3·48	3·10	2·65		

(*d*) **Discussion.** Here again the data show big differences in mean yields for these three species. Relative yields for *Paspalum* and *Phaseolus* (both sub-tropical plants), and for *Medicago* were as 100 : 80 : 10.

Sulphur had no effect on the yield of any species.

Experiment 10

(*a*) **Objective.** To study the effect of selected nutrients on plants growing in "sub-soil" from the lateritic gravel.

(*b*) **Design and Procedure.** For this experiment samples were taken from three locations at a depth of 24-36 inches, and within 6 inches of the under-lying rock. The 'soil' was sieved to remove pebbles above 1/4 inch in diameter, and thoroughly mixed to provide a uniform material, suitable for use in pots. Only one species (*Paspalum commersonii*), and five nutrients (K, P, N, Ca and Mg) were used in a 2^5 factorial experiment. Calcium was applied as $CaCO_3$ (5 cwt./acre), magnesium as $MgSO_4\ 7H_2O$ (4 cwt. acre), mixed with the upper two inches of soil. K was applied as K_2SO_4 (3 cwt. acre) and all other nutrients in forms and doses enumerated for Experiment 1. All pots received a basal dressing of Cu, Zn, Mn, Fe, Mo and B. The *Paspalum* was planted on August 10, 1956, and harvested three times, viz., on September 17, 1956, November 7, 1956, and December 17, 1956. Additional nutrients were added as follows :—

On 30.9.56—5 cwt./acre $(NH_4)_2SO_4$ applied to all pots with added N.
Total dose now ≡ 236 lb./acre of N.

On 9.10.56—4 lb./acre $Na_2B_4O_7.10H_2O$ applied to all pots.
Total dose now ≡ 1.0 lb./acre of B.

On 13.10.56—3 cwt./acre K_2SO_4 applied to all pots with added K
Total dose now ≡ 300 lb./acre of K.

5—J. N. B 65834 (5/57)

Mean relative yields for the Mg treatments were 101 $\pm$ 3.9 for Mg alone, and 100.5 $\pm$ 5.8 for Mg. in combination with Ca.

Complete absence of any response to Mg in these experiments suggests that there is no deficiency of magnesium in this soil. Also, it should be noted that in Experiment 6, a few plants developed symptoms that might have been due to magnesium toxicity. In light of these results and in view of that possibility, it might be wise to withhold any application of magnesium to this soil, pending further investigation of its Mg status.

4. *Minor Elements.* There was no evidence of any deficiency or excess of copper, zinc, manganese, or iron. Molybdenum also had no apparent effect on plant growth, but the delayed effect of Mo on symbiotic nitrogen fixing bacteria (*Rhyzobium*) needs further study.

5. *Root Exhudates.* There was no evidence of any accumulation of soluble toxic substances in this soil, following growth of *Paspalum commersonii.*

6. *Deficiency Symptoms.* The deficiency symptoms that were observed in Experiments 1, 2, and 3 were seen again in Experiment 4 and 6. However, in those experiments it was found that very similar symptoms appeared in the absence of Ca, and with sub-optimal dosage of K. Very few, if any, symptoms of deficiency were seen when both nutrients were applied in sufficient quantity. These symptoms must therefore be attributed to a double deficiency of K and Ca.

Experiment 8

(*a*) **Objective.** To measure the effect of boron on the growth of plants in lateritic gravel soil.

(*b*) **Design and Procedure.** This was a $3^2 \times 4^1$ factorial experiment, using three species (*Paspalum commersonii*, *Medicago sativa*, and *Phaselous lathyroides*) two forms of Calcium ($CaCO_3$ and $Ca(OH)_2$), and three doses of boron. In order to avoid contamination from 'pyrex' glassware, all water used in this experiment was finally distilled from chromium-plated copper apparatus. That water had proved satisfactory in experiments with other soil, wherein boron deficiency was recorded. All pots were given a basal dressing of nitrogen, phosphate, and magnesium; applied in forms and doses enumerated for Experiment 1.

$CaCO_3$ and $Ca(OH)_2$ were applied as equivalent Ca (4 cwt./acre of Ca); boron was applied as $Na_2B_4O_7.10\ H_2O$, at 4, 8, and 12 lb. per acre. The *Paspalum* was planted on September 18, 1956, the *Medicago* on September 24, 1956, and the *Phaseolus* on December 25, 1956. They were harvested on November 12, 1956, November 28, 1956, and January 21, 1957, respectively. On December 25, 1956, (i.e., at time of planting *Phaseolus*) an additional 3 cwt. acre of K_2SO_4 was applied to the soil:—Total dose then 225 lb. acre of K.

(*c*) **Results.** Individual yields and effective treatments are recorded in Table XII.

TABLE XII—Experiment 8—Showing individual Yields, and Level of Significance for all Treatments affecting the Yields of three Species

Species	Treatment	nil	B_4	B_8	B_{12}	Effective Treatments	Levels of significance %
PASPALUM	nil	15.39	12.35	12.66	15.14		
	$Ca(OH)_2$	10.81	11.26	12.25	10.34	Species	·1
	$CaCO_3$	13.41	14.84	14.24	13.66	Sp × Ca	5·0
MEDICAGO	nil	0	0	.08	.23		
	$Ca(OH)_2$	.35	.41	.87	.59		
	$CaCO_3$	.24	.41	.46	.28		
PHASEOLUS	nil	1.17	2.38	.56	1.99		
	$Ca(OH)_2$	3.85	1.45	.81	2.99		
	$CaCO_3$	3.24	2.54	2.81	1.09		

(*d*) **Discussion.** The data show big differences in mean yields for the different species; they were, in part, a reflection of their age at time of harvest. There was also a differential effect from Ca. Calcium did not affect the yield of *Paspalum*, but it was responsible for quite large increments in the yield of legumes. Mean yields of *Phaseolus* were increased by approximately 50 per cent. and those of *Medicago* by more than 450 per cent. Calcium hydroxide ($Ca(OH)_2$) and Calcium Carbonate ($CaCO_3$) were equally effective, and in the absence of Ca, two plants of *Medicago* died.

On 2.11.56—3 cwt./acre of $NaH_2PO_4 2H_2O$ and $CaCl_2$ (≡ 10 cwt./acre of $CaCO_3$) applied to all pots with added P or Ca.
Total dose now ≡ 134 lb./acre of P, 8 cwt./acre of Ca.

On 16.11.56—5 cwt./acre $(NH_4)_2SO_4$ applied to all pots with added N.
Total dose now ≡ 354 lb./acre of N.

(c) **Results.** Individual yields and effective treatments are recorded in Table XIV.

TABLE XIV—Experiment 10—Showing individual Yields, and level of Significance for al Treatments affecting the growth of Paspalum commersonii

Species	*Harvest*	*Treatment*	*nil*	*N*	*P*	*NP*	*Effective Treatments*	*Level of significance %*
PASPALUM COMMERSONII	(1) Age 38 days	nil	·15	1·00	·24	3·73		
		nil K	·25	·62	·38	7·88	N	·1
		Mg nil	·18	·62	·45	·448	P	·1
		Mg K	·37	·71	·58	·6·44	K	1·0
		Ca nil	·19	·66	·49	4·53	NP	·1
		Ca K	·16	·72	·76	6·75	NK	1·0
		Mg Ca nil	·20	·42	·43	4·06	PK	1·0
		Mg Ca K	·23	·38	·72	6·91	NPK	1·0
	(2) Age 89 days	nil	·23	3·15	·31	3·35	N	·1
		nil K	·49	5·21	·44	9·90	P	·1
		Mg nil	·59	3·41	·39	2·47	K	·1
		Mg K	·45	56·0	·53	9·11	NP	·1
		Ca nil	·78	3·36	·58	3·15	NK	·1
		Ca K	·85	4·60	·69	10·21	KP	·1
		Mg Ca nil	·89	3·59	·61	3·42	NPK	·1
		Mg Ca K	·82	4·43	·65	10·55	NPCa	5·0
	(3) Age 129 days	nil	·14	·06	·18	0	N	·1
		nil K	·27	2·32	·15	7·60	P	·1
		Mg nil	·40	·05	·20	0	K	·1
		Mg K	·20	2·44	·26	9·10	NP	·1
		Ca nil	·26	·07	·24	0	NK	·1
		Ca K	·34	2·38	·52	8·67	PK	·1
		Mg Ca nil	·38	1·55	·23	0	NPK	·1
		Mg Ca K	·28	2·34	·34	9·47		

Magnesium had no effect, and the only response to Ca was in the second harvest; when Ca gave a small increment (12 per cent.) in

presence of NPK, and a small decrease (7 per cent) in absence of K. On the other hand, the data for N, P, and K were very precise, (see Fig. 8) and may be summarized as follows :—

First Harvest. In this experiment there was a very big response to NP (2,300 per cent. increment), and a still bigger response to NPK (3,800 per cent. increment). However, it should be noted that N alone gave an increment of 285 per cent. and P alone an increment of 128 per cent.

Second Harvest. In this harvest the response to N alone was much greater (increment of 436 per cent.) and comparable with that from NP (420 per cent.). There was no response to P, alone ; but again, a very big response to NPK (increment of 1,500 per cent.).

Third Harvest. In the third harvest, and in absence of K there was no significant response to any nutrient, and it should be noted that all plants treated with N and P died. In presence of K, N gave an increment of 350 per cent. but there was no response to P. NPK gave an overall increment of 2,750 per cent.

(*d*) **Discussion.** 1. *General.* The data from this experiment were essentially similar to those recorded for Experiment 1, but there was a much greater response to N, P and K in combination, and there were some important differences in the response to N, P, and NP. The

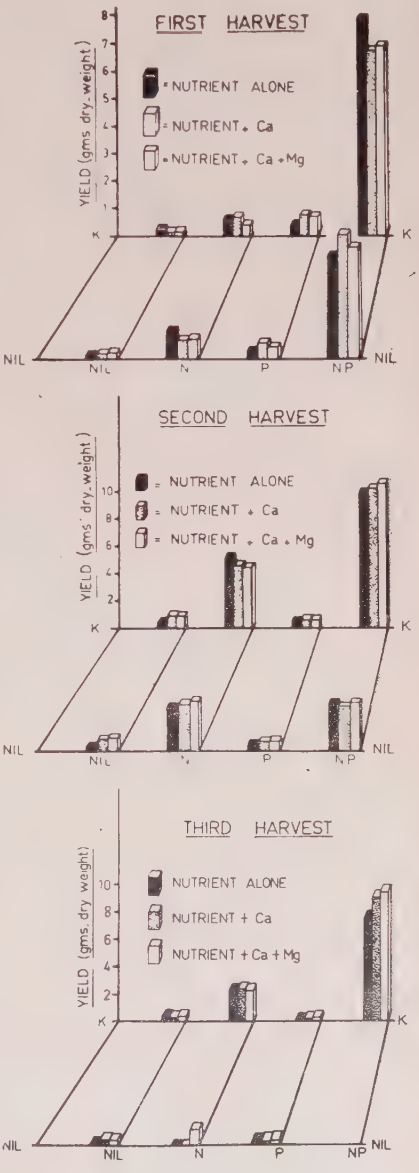


Fig. 8.—*Experiment* 10.—Showing mean yields for all effective treatments in successive harvests of *Paspalum commersonii.*

general pattern of responses is shown in Fig. 9, which was compiled from relative yields in individual replicates, (nil, Ca, Mg and MgCa) to show the mean and standard deviations of relative yields in absence of individual nutrients, and in successive harvests.

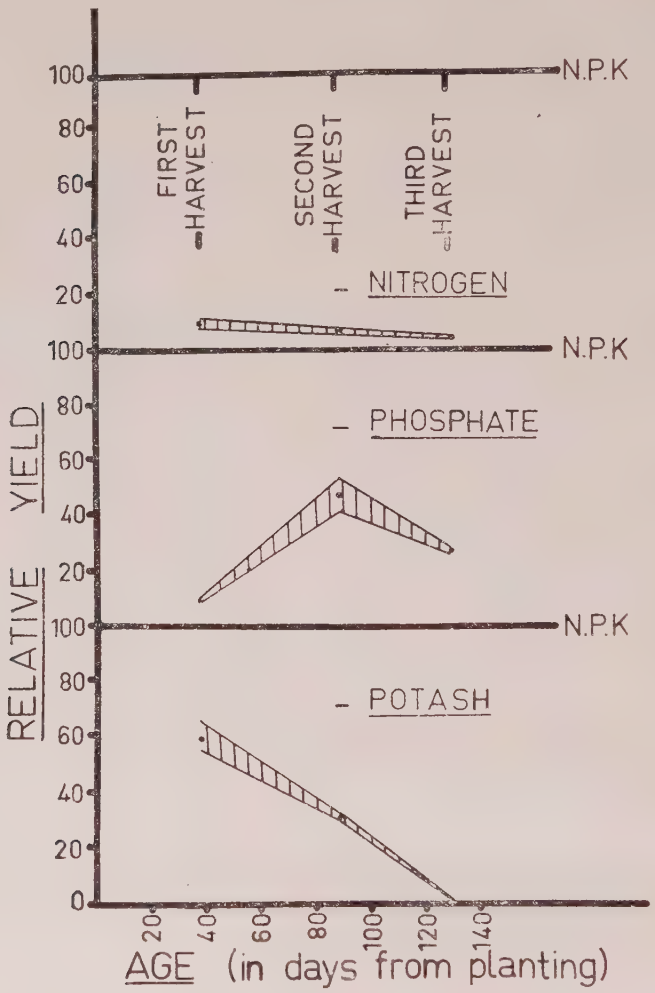


Fig. 9.—*Experiment 10.*—Showing mean and standard deviation of relative yields in the absence of single nutrients, and in successive harvests.

The main similarity between this pattern of responses and that for Experiment 1 (Fig. 5) was the steady decline and death of plants that were grown without any addition of K. The main difference lay in the consistently low yields in absence of N. The trend of yields in absence of P was essentially that portrayed in Fig. 5, except that there

was some (at present unaccountable) depression in the third harvest. In all cases maximum relative yields were appreciably less than those recorded in Experiment 1.

2. *Nitrogen and Phosphate.* In Experiment 1, the initial response to N was comparatively small and the response to P relatively large. In this experiment N (alone) increased yields by 200 per cent. and the increase from P (alone) was much smaller (135 per cent. c.f. 400 per cent. in Experiment 1). However, that difference was more apparent than real : it may be interpreted as showing the presence of some available nitrogen in untreated soils of the previous experiments. In that event the larger response to P (alone) in Experiment 1, would follow from the normal P × N interaction, and in that experiment " P alone " should be read as Pn ; where " n " represents the natural level of available nitrogen in that soil. Again in the second harvest of Experiment 1, the apparent depression from P (alone) would follow from complete exhaustion of " n ", with some advantage to the " nil " treatment. That effect would be comparatively short-lived, and it is significant that in the third harvest, P (alone) had no effect.

In other words the data from these two experiments suggest that surface and sub-soil are essentially similar, except for the higher level of available nitrogen in surface soil and the greater deficiency of all three nutrients (N, P and K) in the sub-soil.

3. *Calcium and Magnesium.* In this experiment there was no significant response to Ca, or to Mg. However, it should be noted from experiment 4, that leaching removed approximately 1 cwt./acre of CaO from surface soil and that natural leaching (rainfall, &c.,) would have a similar effect. It follows that in course of time the surface soil would show a degree of Ca deficiency ; which was in fact recorded in Experiment 6.

SUMMARY AND CONCLUSIONS

1. For the purposes of this investigation the lateritic soils on Bandirippuwa Estate have been briefly described and three variants, " lateritic gravel ", " lateritic loam " and " lateritic sand " have been defined. This bulletin records experiments on the ' lateritic gravel '.

2. The data show that this soil is deficient in nitrogen, phosphate and potash, and that there is a consistent pattern of responses with some change in nutrient status over a period of time. There is also a deficiency of calcium, which may be resultant on natural leaching of the surface soil.

3. There was no apparent deficiency of magnesium, and application of magnesium to this soil is not recommended.

4. There was no apparent deficiency of sulphur, or of trace elements :—copper, zinc, manganese, iron and boron. Molybdenum had no apparent effect on plant growth, but the delayed effect of molybdenum on symbiotic legume bacteria (*Rhyzobium*) needs further investigation.

5. Nitrogen was at all times an important limiting factor in plant growth, and on the basis of 100 per cent. for plants receiving N, P and K, relative yields for the grass *Paspalum commersonii*—grown without any application of nitrogenous fertilizer—decreased steadily from an initial value of 50 per cent. in the first harvest, to 15 per cent. in all subsequent harvests. The sub-soil contains even less available nitrogen. and yields decreased steadily to a consistent value of less than 10 per cent. Yields of a legume, *Phaseolus lathyroides,* rose steadily to an asymptote at 100 per cent. indicating effective nodulation.

6. The amount of nitrogen required for satisfactory plant growth has not been determined, but in pot experiments doses of 5-15 cwt. $(NH_4)_2SO_4$ were used to maintain satisfactory growth over a period of six months. Excess nitrogen (+ phosphate), in absence of sufficient K, gave unsatisfactory yields, and was responsible for the death of some plants.

Under field conditions, plants of *Paspalum commersonii* did not show the same *acute* nitrogen deficiency, and it is likely that frequent, small doses would be more economic, and equally effective. Use of green manures, or of highly productive grass pastures—whereon the animals were fed a supplementary ration of protein (poonac)—would seem to be an obvious alternative : both would require optimal dressings of potash, phosphate and calcium.

7. In the early stages of growth there was an acute deficiency of phosphate and relative yields for plants grown in surface and in subsoil were as low as 20 per cent. and 9 per cent., respectively. However, there was a general trend towards increasing yields (without any application of phosphate fertilizer) and in subsequent harvests relative yields of 70 per cent. and 45 per cent. were recorded.

In pot experiments, applications of 3 cwt./acre of $NaH_2PO.2H_2O$ were sufficient to maintain satisfactory growth of both grass and legume.

8. A deficiency of potash has been established, and it is a point of peculiar interest that in the absence of potassic fertilizers, relative yields did not tend towards an asymptote, and plants of *Paspalum commersonii* eventually died. The data suggest that available potash

in this soil is gradually fixed, and this is supported by chemical evidence, and by experiments wherein the soil was aerated and dried. Following that simple treatment, soil whereon most plants of *Paspalum* had died was replanted and gave relative yields of more than 80 per cent.

With no application of potassic fertilizer, the sub-soil gave initial yields of 60 per cent., but after 114 days all plants of *Paspalum* were dead. The surface soil initially gave relative yields of over 90 per cent., and after 150 days most plants were dead.

The capacity of this soil to fix available potash is apparently limited, and applications of 4½ cwt. K_2SO per acre were sufficient to maintain plant growth. Doses up to 10 cwt./acre gave no further increase in yield. That rate of application was in respect to soil sampled to a depth of nine inches, and it is possible that under field conditions, and in time, some further application would be required.

A deficiency of Calcium was recorded only in surface soil, where applications of 10 cwt. $CaCO_3$ per acre were sufficient to meet all requirements. It is possible that a smaller dosage would be equally effective.

ACKNOWLEDGMENT

The authors wish to express their appreciation of assistance and advice from all members of the Coconut Research Institute staff ; in Mr. V. Abeywardena (Biometrician) for his advice on the design of experiments and analysis of data ; to Mr. W. R. N. Nathanael and Mr. V. Nalliah for chemical analysis of plants and soils, and to Mesdames Beryl Salmond and M. Ginger for their active participation in the great majority of experiments. All diagrams and plates were photographed by Mr. B. Hettiarachchi ; the typescript was prepared by Mr. R. de Almeida.

The senior author wishes to express appreciation of the extensive facilities for research afforded by the Coconut Research Institute, and members of the Coconut Research Board.

REFERENCES

(1) Paltridge, T. B., *Sown Pastures for South Eastern Queensland.* C.S.I.R.O. Bulletin No. 274, Melbourne, Australia, 1955.

(2) Wickremasinghe, T. (Ceylon Department of Agriculture)—*Unpublished data.*

(Received 9 March 1957)

AN ANALYSIS OF THE EUROPEAN HERDS OF DAIRY CATTLE AT AMBAWELA AND BOPATALAWA*

By P. MAHADEVAN
(*Livestock Research Officer—Department of Agriculture, Ceylon*)

INTRODUCTION

THE FIRST large-scale importation of temperate breeds of cattle to Ceylon was made in 1943 when 300 cows and 36 bulls were imported from Australia by the Ceylon Government. This was followed by the importation of a further 595 head from the same country in 1944. These two importations provided the foundation stock for the large herds of European cattle that now populate the Government Cattle Farms at Ambawela (elevation 6,000 ft.) and Bopatalawa (elevation 5,000 ft.) in the central hills of Ceylon. A few occasional importations in more recent times, from Australia and from Great Britain, of a small number of heifers and stud bulls, have also been recorded.

The climatic conditions prevailing at Ambawela and Bopatalawa have been conducive to the well-being of these cattle. The mean monthly temperature at Ambawela, for example, is under 60°F., and because temperature in this part of the country is controlled mainly by the topography of the land, seasonal variations are very slight. But, the daily temperature range is considerable and averages about 20°F. The mean relative humidity is around 75 per cent., but a close relationship is known to exist between daily temperature range and relative humidity, the latter being lowest during the relatively dry months of February and March when the daily temperature range is greatest. Frost may sometimes occur during these months as a result of the ground temperature occasionally dropping below zero during the night. However, the incidence of frost rarely exceeds four or five days for a whole year. Rainfall is fairly evenly distributed although the period December to March often tends to be relatively dry. The total precipitation for the year is about 110 in. at Ambawela and 82 in. at Bopatalawa, and the total number of rainy days in the year averages 235 and 186 respectively.

*Further details of this analysis are published in the Journal of Agricultural Science 1957, under the title *Variation in Performance of European Dairy Cattle in Ceylon.*

The acidity of the soils at these farms (pH 5.3) was a serious obstacle to pasture establishment in the early years, as most pasture grasses cannot grow under these conditions. The natural vegetation consists of tufted, coarse, and wiry grasses, chiefly represented by *Chrysopogon, Ischaemum* and *Themeda* species and a few legumes such as *Smithia blanda, Cassia mimosoides* and *Desmodium* spp. Heavy liming of these *patana* soils had to be undertaken before the introduction of any cultivated species of fodder or pasture. With the introduction of buckwheat (*Fagopyrum sagittatum*) into these farms in 1951, however, the reclamation of *patana* land has proved to be less expensive, as buckwheat tolerates acidity of soils to a large extent. The cultivation of *patana* soils now takes the following sequence : buckwheat—lupins and sunflower—radish—pasture. The major pasture components in the cultivated areas are kikuyu, ryegrass, cocksfoot and clovers.

It would thus be evident that the environmental conditions under which European cattle are reared at Ambawela and Bopatalawa, though differing in a number of respects from those obtaining in temperate countries, are nevertheless not unsuited to them.

DESCRIPTION OF DATA

The herds whose records have been analysed in this work belong to five breeds : Ayrshire, Friesian, Shorthorn, Red Poll and Jersey. With the exception of the Ayrshire herd which is at Ambawela, the remaining four herds are housed at Bopatalawa. The total number of records analysed in this study consisted of 2,868 lactation records from 871 cows, approximately 36 per cent. of which were Ayrshire, 28 per cent. Friesian, 18 per cent. Shorthorn, 11 per cent. Red Poll and 7 per cent. Jersey.

All five breeds are maintained on a moderately high plane of nutrition, though in the early years of development of the farms conditions were not so satisfactory. In addition to grazing and cut green fodder, all milking animals are allowed on the average. 1 lb. of concentrates to every 2 lb. of milk. Cows in late pregnancy and young stock are also given a liberal allowance of concentrates. The main components of the concentrate ration are coconut poonac, rice bran and fish meal, all of which are produced in the country and therefore available at low cost. Standard mineral mixture is incorporated to the extent of about 3 per cent. of the total concentrate ration of all animals.

RESULTS

The means and variations of the main production traits are presented in Table 1. The mean age at first calving among the European breeds, with the exception of the Jersey, was 40 $\pm$ 0.4 months. The Jersey,

which is represented by a small herd, averaged 30 months at calving. A concentrated effort is now being made to lower the age at first calving by improved feeding and management of young stock. The indications are that a considerable reduction in age at first calving could be attained although it may not be possible to lower it immediately to the level obtaining in European countries.

TABLE 1—Means and Variations

Trait	*Breed*	*Mean*	*Coefficient of Variation*
Age at first calving	Ayrshire	40 months	
	Friesian	40 months	
	Shorthorn	41 months	19%
	Red Poll	41 months	
	Jersey	30 months	
First lactation 305 day Milk yield ..	Ayrshire	377 gls.	
	Friesian	461 gls.	
	Shorthorn	379 gls.	36%
	Red Poll	317 gls.	
	Jersey	279 gls.	
Length of lactation	All breeds	320 days	27%
Calving interval	All breeds	466 days	34%
Dry period	All breeds	135 days	100%

The average first lactation yield has varied from breed to breed and from period to period since the inception of the farms at Ambawela and Bopatalawa. The yield figures presented in Table 1 are for the whole period from 1943 to 1954. They may be compared with average yields during 1954-5 of 511, 625, 463, 462 and 418 gallons respectively in the Ayrshire, Friesian, Shorthorn, Redpoll and Jersey herds. Variations in age at first calving were found to exert a marked influence on the first lactation yield in the Ayrshire and Friesian breeds where the regressions of yield on age at first calving were 6.6 and 11.0 gallons respectively per month.

The mean length of calving interval in the total data was 466 days as shown in Table 1, but in recent years it has been lowered appreciably and the average during 1951-4 was 413 days, which is not very different from that in European cattle in temperate countries. A similar decrease in length of dry period from about 135 days to 100 days has also been achieved.

Perhaps the most interesting feature of Table 1 is the high coefficients of variation obtained for all production traits. These coefficients are almost twice as large as the corresponding coefficients of variation for cattle in temperate countries.

VARIATION OF YIELD WITH AGE

The results obtained by the paired lactation method showed that peak production in the herds at Ambawela and Bopatalawa was generally attained by the third lactation. In the case of European cattle in their home environment, the peak of production is usually later, by about the fourth or fifth lactation. This difference in the age effects of European cattle in temperate countries and in Ceylon may perhaps be due to the late age at first calving of these cattle in the tropics. The average increase in yield from first to second lactation in the present material was 16.5 per cent., and that from second to third lactation 4.2 per cent. Though the former value is rather more and the latter rather less than in European cattle in temperate countries, the overall increase in yield with age is closer to that in Europe than to that in Zebu cattle in the tropics.

CORRELATIONS—LACTATION YIELD, LACTATION LENGTH AND AVERAGE DAILY YIELD

As lactations vary little in length in the more advanced dairying countries, the main factor governing the lactation yield of dairy cattle in those areas is the maximum daily yield. But, with Zebu cattle in the tropics there is generally a high correlation between yield and lactation length as well. One might then ask to what extent these differences between European and Zebu cattle are genetic. The results summarised in Table 2, based on the analyses of data collected for different breeds in Ceylon and also on analyses that we have carried out of records published in *Misc. Bull. I.C.A.R. No. 36 (1941), India,* seem to provide an answer to this question.

TABLE 2—Intra-herd Intra-cow Correlations between Lactation Yield and Lactation Length and between Lactation Yield and average Daily Yield

Breed	*Source of Data*	*No. of records*	*Correlations*	
			Lact. yield and Lact. length	*Lact. yield and average daily yield*
Sinhala ..	Ceylon	333	0·44	0·82
Red Sindhi ..	Ceylon	696	0·60	0·78
Sahiwal ..	Misc. Bull I. C. A. R. No. 36, India	237	0·42	0·79
¼ European × Zebu ..	,,	327	0·51	0·72
½ European × Zebu ..	,,	996	0·49	0·76
¾ European × Zebu ..	,,	519	0·55	0·78
European ..	Ceylon	1566	0·50	0·72

It will be seen from this table that the high correlation between yield and lactation length observed in tropical countries is not a trait that is peculiar to Zebu cattle. It appears to be common to all stock reared under the conditions of management prevailing in tropical areas, irrespective of whether the population is purebred Zebu, purebred European or crossbred. It is therefore improbable that the relationship usually observed between yield and lactation length for Zebu cattle in the tropics is due to the genetic make-up of these cattle.

REPEATABILITY

The within-herd correlation of the yield in one lactation with that in the next for the same cow was found to be 0.5. The corresponding figures for average daily yield and lactation length were 0.4 and 0.27. These figures indicate the extent to which the respective traits are permanent characteristics of the cow. The figure 0.5 for yield agrees closely with the estimates of repeatability of this trait in Zebu and crossbred cattle in the tropics and in European cattle in temperate environments. So that, despite the high coefficients of variation found for milk yield in dairy cattle when reared in tropical countries, a good part of the variation is still due to permanent differences between cows.

With repeatability of the order of 0.5 for lactation yield and 0.4 for average daily yield, culling of cows on the basis of either of these traits, but preferably on the former, could be carried out early in the life of the cow. The intra-herd correlation between the length of one lactation and the next of the same cow (0.27 ± 0.02), though statistically significant in these data, is not sufficiently high to warrant the culling of cows on the basis of length of lactation even if longer lactations are desired. Moreover, since the phenotypic correlation and presumably also the genetic correlation between lactation length and yield is not perfect, selection of cows on lactation length would tend to lower the intensity of selection for yield.

In regard to calving interval and dry period, the intra-herd correlations were found to be 0.15 and 0.07 respectively. It would be seen from these figures and from the rapid decrease in length of calving intervals and dry periods in recent years in these herds, that calving interval and dry period are almost entirely under the control of management and have little or no genetic component. Although this conclusion may appear difficult to reconcile with the results reported for dry period in temperate environments, it is nevertheless

understandable if it is borne in mind that the average length of dry period in the present data is so much longer than optimum that existing genetic variations between cows in length of dry period are more or less completely masked by management factors. The same explanation would account for the low repeatability of dry period in Zebu cattle in tropical countries.

HERITABILITY

It is known that the method of doubling the intra-sire regression of daughter's record on dam's record would give the most reliable estimate of heritability in data relating to dairy cattle production, where, in general, the dams are likely to have been rather more highly selected than the daughters. In the present data, however, there was reason to believe that the intra-sire correlation would provide a more dependable estimate of heritability than the intra-sire regression. For a regression coefficient to be valid, it is important that distribution of the independent variate should not exist or at the most it should be very reduced. In the current data, the coefficients of variation of milk yield in different periods since the inception of the herds were such that the dams appeared to be a more highly variable population than the daughters. Moreover, whatever selection pressure was applied to milk yield during the early years was small, and in consequence the population of dams may be regarded as an unselected lot in so far as milk yields were concerned. The unselected nature of the dams (most of which were imported), when considered in conjunction with their high variability, warrants the use of the intra-sire correlation for estimating heritability in these data, in preference to the intra-sire regression.

Records used for estimating heritability were all standardised for variations in age and for yearly variations caused largely by improvements in management. It was found that the heritability of single records of milk yield in the population was 0.18 when using the intra-sire correlation and 0.16 when using the intra-sire regression. This means that about one-third of the permanent differences or roughly one-sixth of all differences between cows in the population are additively genetic.

Table 3 summarises the results obtained from different studies of the repeatability and heritability of milk yield in purebred Zebu, purebred European and crossbred stock in tropical areas and in purebred European stock in temperate areas. The similarity of the estimates is striking.

TABLE 3—Repeatability and Heritability of Milk Yield in Dairy Cattle in Tropical and Temperate Countries

Breed	*Repeatability*	*Heritability*	*Reference*
Purebred Zebu cattle in Nigeria ..	0·60	0·32	Robertson (1950)
Purebred Zebu cattle in Ceylon ..	0·46	0·20	Mahadevan (1955)
Crossbred cattle in Jamaica ..	—	0·24	Lecky (1950)
Crossbred cattle in India ..	0·53	0·19	Mahadevan (1954)
Purebred European Cattle in Ceylon	0·51	0·18	Current data
Purebred European Cattle in temperate countries	0·5	0.2–0.3	Most studies

GENETIC CHANGES IN THE HERDS

Any attempt to improve the genetic level of a herd of dairy cattle is basically dependent on the prevailing mortality rates, rearing proportions and total reproductive rates. With high reproductive and low mortality rates and with high rearing proportions, the intensity of selection possible would be high, and vice-versa. In the present study, it was found that during the period prior to 1951 the average reproductive rate, when measured as a sum of the partial reproductive rates in the different years, was 0.38. This means that, on the average, about every five cows produced in their lifetime two heifer calves that came into milk in the herd. Rearing proportions were also low, and it was only once in about 5 calvings that a cow produced a heifer calf which reached a lactation in the herd. Associated with this was the high mortality rate that prevailed in the herds during this period. In fact, of every 100 heifers born at that time, 39 died before first calving.

In the light of this, it is not surprising that in the majority of these herds no overall genetic progress in milk production was made up to 1950 by selection of dams of heifers. During the period after 1950, however, when the average mortality rate among heifers was reduced to 24 per cent., and when total reproductive rates increased to 0.68, the intensity of selection possible has been greater and a positive selection pressure appears to have been exerted in practically every herd. This is reflected to some extent in the high lactation yields now obtaining at Ambawela and Bopatalawa.

The sires used until 1950 were all imported, and it is only in recent years, with the introduction of a programme of progeny testing young bulls in the large Ayrshire and Friesian herds, that

farmbred bulls are being used. In order to keep generation intervals as low as possible, young bulls earmarked for testing are reared on a high plane of nutrition during early life so that they are in fit bodily condition for service when they are about 1½ years of age. This aspect of dairy cattle management is of some importance in the tropics where age at first service in males and age at first calving in females tend to be delayed in most herds. The mean generation interval in the present material ranged from 3 years 9 months in the Jersey herd to nearly 7 years in the Red Poll, with an overall mean of 5 years.

DISCUSSION

It is well known that the causes of variation between individuals are differences in the heredity with which they started life, and differences in the environments, both known and unknown, that affect them during their development. The proportion of the variation attributable to each of these two causes differs from trait to trait and from population to population. For characteristics of economic importance in farm animals, such as milk production and other associated traits in dairy cattle, there is generally a high degree of variation.

Although the bulk of the work on the analysis of variation in dairy cattle production has been conducted with European stock in temperate countries, the few studies that have recently been made of tropical dairy cattle serve to emphasise the considerably greater variability obtaining in the latter material. One might therefore ask whether the greater variation within tropical breeds is due to greater differences in the heredity of the animals comprising the breed or to greater differences in the environment to which they are exposed. The results obtained here, when considered in conjunction with previous work on European, Zebu, and crossbred stock suggest that the latter is much nearer what happens than the former.

This conclusion is borne out to some extent by the coefficients of variation obtained in the present study. Although these data relate to purebred European cattle, the results on variability resemble more closely those found for Zebu cattle in the tropics than those for European cattle in temperate countries. The within-breed coefficient of variation of age at first calving, for instance, is 19 per cent. in the present material, as compared with about 10 per cent. for dairy cattle in temperate areas. Similarly, the coefficients of variation of lactation yield, lactation length, average daily yield, calving interval and dry period, which are approximately 36 per cent., 27 per cent.,

34 per cent., 34 per cent. and 100 per cent., respectively in the present data, are of the same order as those found for Zebu cattle in Ceylon, but almost twice as large as those found for dairy cattle in European countries. The conclusion may therefore be drawn that differences in the extent of variation in most economic characters between stock reared in tropical and temperate countries, are due more to differences in husbandry than to any great inherent differences between tropical and temperate breeds of cattle.

That the genetics of milk production in tropical dairy cattle is fundamentally very similar to that of temperate zone cattle is further evidenced by the similarity of the estimates of repeatability and heritability of milk yield arrived at for purebred Zebu, purebred European and crossbred stock in tropical areas, and for purebred European stock in temperate areas. These results are summarized in Table 3.

But there appears to be one important difference between European and Zebu cattle that cannot be entirely attributed to management, and that is the effect of age on yield. In the Zebu, the effect of age on yield is generally much less than it is in European cattle. Among Zebu breeds in Ceylon such as the Red Sindhi, the increase in yield from first to fourth lactation is only 6 per cent. This may be compared with values ranging from 19 to 32 per cent. in the present herds and with similar figures for European cattle in temperate countries. Although part of the differences in the age-changes of European and tropical cattle may be due to management factors, it appears likely that variations in the extent to which the two groups of cattle have been selected for milk production since the time of their domestication may also play some part.

Be that as it may, the differences between European and Zebu stock in regard to most of the parameters that have been calculated here appear to be rather of an animal husbandry than of a genetic nature. It would seem therefore that with the gradual advancement of husbandry techniques in tropical areas, the genetic situation among cattle in the tropics could be more clearly shown to follow the pattern in European dairy countries.

SUMMARY

The existence of a high degree of variability in all production traits of cattle in tropical countries has been demonstrated. Evidence has been adduced to show that this is due more to increased environmental variability than to any great inherent differences between

animals. The conclusion is drawn that despite minor differences, the genetics of milk production in tropical dairy cattle is fundamentally very similar to that in European stock.

REFERENCES

LECKY, T.P. *Cattle Breeding in Jamaica.* Conf. Improvement of Livestock under Tropical Conditions. Edinburgh, Scotland, December 12, 1950 (Mimeographed report).

MAHADEVAN, P. 1954. *Repeatability and Heritability of Milk Yield in crosses between Indian and European breeds of dairy cattle.* Empire J. Exp. Agric. *22 :* 93-96.

MAHADEVAN, P. 1955. *Population and Production Characteristics of Red Sindhi cattle.* J. Dairy Sci. *38 :* 1231-1241.

ROBERTSON, A. *A preliminary report on the herd of Fulani cattle at Shika, Nigeria.* Conf. Improvement of Livestock under Tropical Conditions. Edinburgh, Scotland, Dec. 12, 1950 (Mimeographed report).

(Received 7 March 1957)

Part IV.

INDIGENOUS & EXOTIC DRUG PLANTS GROWN IN CEYLON

By D. M. A. JAYAWEERA

(*Superintendent, Botanic Gardens Ceylon*)

DERRIS—Derris

THE DRIED rhizome and roots of *Derris elliptica,* Benth. and *Derris malaccensis,* Prain. large, woody, evergreen, climbing plants, indigenous to Malaya and East Indies constitute the derris of commerce. They belong to the family Leguminosae and are much cultivated in the Federated Malay States, Sumatra, Java, Johore, Singapore, Philippines and Belgian Congo. The roots are flexible, hard and tough and have an aromatic odour and bitter taste. *Derris elliptica,* Benth. which can be grown in Ceylon is a woody, evergreen climber attaining a length of over 50 feet. Leaves long stalked, pinnate, about 6 inches long ; leaflets, 11-13 elliptic ovate, the terminal one obovate, $1\frac{1}{4}$-$2\frac{1}{2}$ inches long and hairy along the veins. Flowers, pink in axillary racemes, 4-5 flowers arising from each node. Fruit a legume about $1\frac{3}{4}$ inches long. (FIG. 1.)

The plant is propagated by cuttings and thrives best in a rich friable loam up to an elevation of 4000 ft. above sea level with an even rainfall of 90-130 inches per year, at a mean temperature of about 85°F. The crop is harvested two years after planting and the yield is anything from 1000 lb. to 16,000 lb. of dry roots per acre.

Composition. Derris contains a non-volatile colourless crystalline substance called rotenone along with three other crystalline substances—deguelin, tephrosin and toxicarol.

Uses. Derris is extremely poisonous to cold-blooded organisms such as insects and fish owing to the presence of rotenone and hence is used extensively as an insecticide and fish poison. In recent years it has been successfully used in the treatment of scabies. As a powder emulsified with soap and water it serves to protect cattle against the warble fly.

Parts I, II and III of this series were published in the Tropical Agriculturist, *Vol. CI, 1945 ; Vol. CVIII, 1952 and Vol. CX, 1954.*

Fig. 1. *Derris elliptica*, Benth.
Young flowering racemes and tender leaves

EUPHORBIA—Euphorbia

The entire dried plant of *Euphorbia hirta*, Linn. (S. Budadakiriya ; T. Palavi ; Skt. Pusitoa) collected at the time of flowering and fruiting is used medicinally. It is an obliquely erect annual belonging to the family Euphorbiaceae. It is indigenous to India and occurs as a roadside weed in Ceylon. The plant is an annual herb, 6-12 inches high, decumbent, ascending or erect, cylindrical, rather stout with more or less copious spreading bristly hairs. Leaves opposite, $\frac{3}{4}$-$1\frac{1}{2}$ inches long, very shortly petioled, lanceolate-oblong, very unequal sided, serrate, sparingly hairy on both surfaces, pale glaucous or pinkish with prominent veins beneath. Flowers, monoecious, numerous, small without a perianth, many males and one female arranged in a common perianth-like involucre to form a single flower head of which are crowded into small, rounded, pedunculate, axillary cymes. Fruit is a minute hairy

capsule of 3 cocci separating from a central axis each splitting both ventrally and dorsally. (FIG. 2.)

Composition. Euphorbia contains quercetin, triacontane, jambulol, a phenolic substance, euphosterol, a phytosterol and phytosterolin, gallic, melissic, palmitic, oleic and linoleic acids, 1-inositol and an alkaloid Xanthorhamnin.

Uses. Euphorbia has a depressant action on the heart and respiration. It relaxes the bronchii by its central action. It is administered in the form of a liquid extract or tincture, with lobelia or senega in the treatment of asthma, chronic bronchitis, emphysema, coryza and hay fever.

Fig. 2. *Euphorbia hirta*, Linn
Two whole plants showing roots, leaves and branches with flower heads

FOENICULUM—Fennel

Fennel consists of the dried ripe fruits of *Foeniculum vulgare,* Mill. (S. Ma-duru ; T. Sombu ; Skt. Madhurika.) a short lived perennial herb with a thick rootstock belonging to the family Umbelliferae. The plant is about 2-4 feet in height with long petioled, 3 or 4 times pinnate leaves ending in narrow linear awl-shaped segments. Flowers are borne in long stalked compound umbels each carrying 15-20 bright yellow flowers. The fruit is an oblong, laterally compressed greenish grey glabrous cremocarp about 1/5 inch in length with a short bifid stylopod carrying abundant oily endosperm.

The plant is indigenous to countries bordering the Mediterranean but is extensively cultivated in the central parts of Europe, China and India.

History. Fennel was known to the ancient Chinese, Indians, Egyptians and Romans both for its culinary and medicinal value. It was known in Northern Europe in the 11th century. Its cultivation was encouraged in Central Europe by Charlemagne particularly in his imperial farms. Mention has been made of the uses of the various parts of this plant in ancient records of Spanish agriculture dating as far back as 961 A.D.

Composition. The chief constituents of fennel oil are anethol and a colourless pungent liquid called fenchone which possesses a camphoraceous odour and taste. In addition it contains pinene, methyl chavicol and anise ketone.

Uses. Fennel is used medicinally as a carminative by virtue of the volatile oil it contains. It allays gripe and removes flatulence. It is much used for culinary purposes and for flavouring confectionary and liqueurs.

GENTIANA—Gentian

Gentian consists of the dried fermented root and rhizome of *Gentiana lutea,* Linn. a herbaceous perennial indigenous to Central Europe belonging to the family Gentiaceae. A suitable substitute for gentian is found in the dried stem bark of *Azadirachta indica,* A. Juss. (S. Kohomba ; T. Vempu ; Skt. Nimba.) a tall handsome ornamental shade tree with long spreading branches. It belongs to the family Meliaceae and is indigenous to South India, Ceylon and Malay Archipelago. The tree attains a considerable girth and height. The leaves are pinnate rather crowded while individual leaflets are shortly stalked, 2-4 inches, lanceolate—falcate, very unequal sided, oblique at base, coarsely dentate—serrate, glabrous and pale green in colour. Flowers

are small, white, sweet-scented and are borne in lax, narrow axillary panicles. The fruit is an oblong-ovoid dark purple drupe with a bony endocarp carrying a solitary seed.

History. The tree under its Sanskrit name "Nimba" is mentioned in one of the most ancient Hindu Medical writings. Garcia d'Orta, physician to the Portuguese Viceroy of Goa, published an account of it in 1563, while its properties have been long recognized by the native physicians of India and Ceylon from time immemorial.

Composition. Azadirachta bark yields very small quantities of a bitter alkaloid, margosine with tannin while the leaves and fruits yield the alkaloids paraisine and azaridine respectively.

Uses. In India and other Eastern countries the bark is employed as an equivalent of gentian and quassia and administered in the form of a tincture or infusion.

In the Ayurvedic system of medicine the bark is used in cases of intermittent fevers and loss of appetite while the juice of fresh leaves is given for intestinal worms, jaundice and skin diseases. The gum obtained from the bark is used in catarrhal and other similar affections. The oil obtained from seed is used as an external application for rheumatism, leprosy, urticaria, eczema and other skin diseases.

It is a common practice among the indigenous population to drink the oil along with garlic and powdered ginger immediately after confinement and burn the oil morning and evening in the labour room for 30 days, perhaps to serve as a disinfectant.

IPECACUANHA—Ipecacuanha

The dried root of *Cephaelis ipecacuanha,* A. Rich. a small erect shrub of about 8 to 16 inches in height with a somewhat creeping root usually found growing in moist shady forests of South America constitutes the ipecacuanha of the British Pharamacopoeia. It belongs to the family Rubiaceae and is a native of South America especially in the Brazilian provinces of Para, Maranhao, Pernambuco, Bahia, Espiritu Santo Minas, Rio de Janeiro, Sao Paulo and also in New Granada and Bolivia.

The plant in its natural habitat is found under the thick shade of very old trees, growing mostly in clumps. The leaves are few somewhat crowded at the upper part of the stem, opposite, oval with large stipules united at the base. Flowers are small, sessile in a dense head supported on an apparently terminal peduncle surrounded by an involucre of four ovate unequal bracts. Fruits are many in a small cluster and deep purple in colour, each containing a solitary seed with abundant horny endosperm. (Fig. 3.)

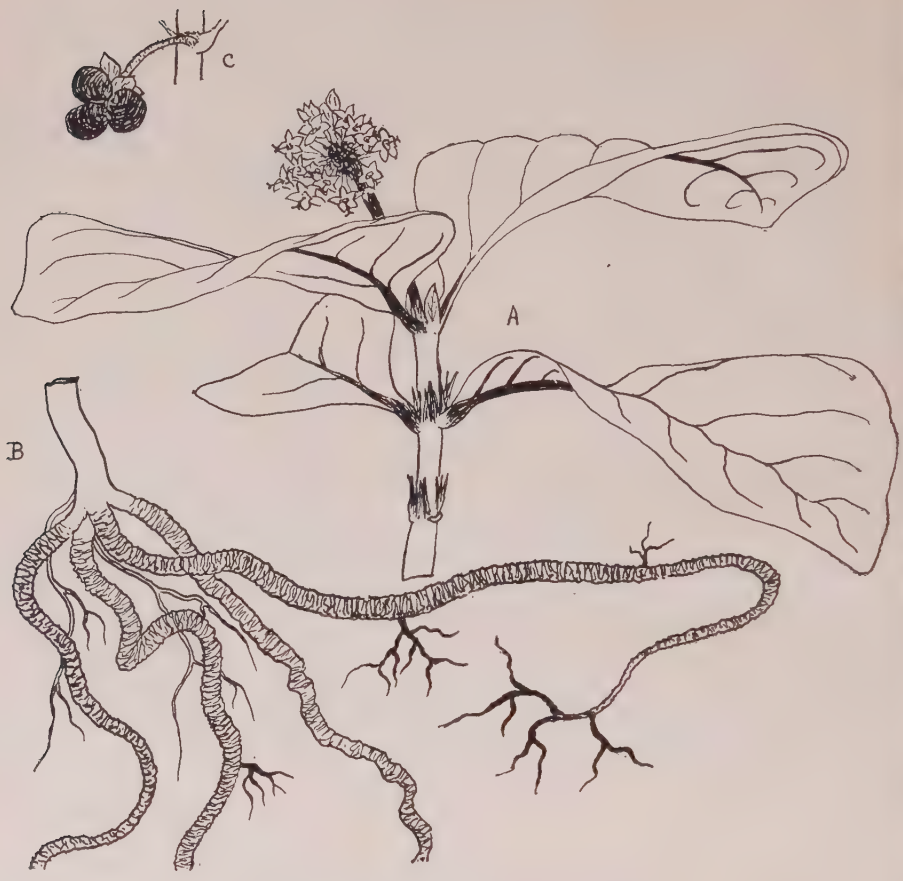


Fig. 3. *Cephalis ipecacuanha*, A. Rich.
A. Upper part of the plant showing leaves, stipules and inflorescence
B. Lower part and root. C. Cluster of fruits.

The plant is propagated from root cuttings, each piece of the root however small throwing out a leaf bud and becoming an independent plant or from petiolar cuttings. An attempt was made to acclimatise the plant in India and Ceylon with a moderate amount of success.

History. The earliest account of the plant was written by a Portuguese friar who had resided in Brazil from 1570-1600. Later Piso and Marcgraf in their scientific exploration of Brazil described two varieties of the plant. The drug was not known in Europe before 1672. About this time a physician named Legras brought a quantity of the root from S. America to Paris, but administering too large doses damaged its reputation. In 1686 a merchant named Grenier came into possession of 150 lb. of the drug, the properties of which he confided

to his physician Afforty who took no notice of it, but his pupil Helvetius on the other hand earned quite a reputation by curing several cases of dysentery with the drug. The fame of his cures reached the French Court, and after successful trials Louis XIV gave the sole right of dispensing this drug to Helvetius. Subsequently the King bought the secret from Helvetius and published it.

Composition. Ipecacuanha contains the alkaloids emetine, cephaeline, psychotrine, 0—methylpsychotrine, ematamine and in addition ipecacuanhic acid, the glycocide, ipecacuanhin, a saponin and much starch.

Uses. Ipecacuanha is given in small doses as an expectorant in acute and chronic bronchitis and in cough when secretion is scanty. In large doses it is used as an emetic in the treatment of amoebic dysentery.

LINUM—Linseed

Linseed is the dried ripe seeds of *Linum usitatissimum,* Linn. a stiff upright annual with alternate sessile linear—lanceolate leaves belonging to the family Linaceae. Flowers occur solitary at the ends of

Fig. 4. *Linum usitatissimum,* Linn.

A. A branch showing leaves and flowers B. Ripe Fruit.

branches deep violet—blue in colour. The fruit is a flask-shaped 5-celled capsule carrying 10 flattened elongated ovoid seeds. Its country of origin is impossible to be determined as its cultivation can be traced back to the remotest periods of history. (FIG. 4.)

History. The linseed plant as a source of its textile fibre and seed is closely connected with human civilization. The whole process of extraction of the fibre and weaving it into cloth is depicted in the wall paintings in Egyptian tombs. Further the grave clothes of the old Egyptians were made of flax and according to Unger this could be traced back to the 23rd century B.C. and Pliny among the Romans mentions linseed as an article of food. Pliny and Dioscorides were acquainted with its medicinal uses. The cultivation of flax was encouraged by Charlemagne in Northern Europe.

Composition. Linseed contains 30 to 40 per cent. fixed oil, 4.4 to 8.7 per cent. mucilage from the seed coat and 25 per cent. proteids.

Uses. In medicine, crushed linseed (Linum contusum) is chiefly used as a poultice for the relief of superficial or deep-seated inflammation. Pure linseed oil (Oleum Lini) is used internally as a laxative and also in the treatment of burns or scalds. Principally the commercial oil is used in painting, on account of its drying property, and in the manufacture of printer's ink. The flax from the plant is used intensively for manufacture of linen fabrics, lint which is so valuable for surgical dressings and tow which is much employed in pharmacy, surgery, &c.

MYRISTICA—Nutmeg

Nutmeg consists of the dried kernels of the seeds of *Myristica fragrans*, Houtt, a medium evergreen tree with much spreading branches belonging to the family Myristicaceae. It is a native of Moluccas and the neighbouring islands and much cultivated in the Philippines, Penang, Singapore, Mauritius, West Indies and South America. The tree is dioecious, male trees being more frequent than female trees. One male tree furnishes sufficient pollen for about 20 female trees. Its leaves are alternate, shortly petioled, exstipulate, somewhat convex above, 4-6 inches long, ovate or oblong-ovate, dark green and paler beneath. Flowers occur in axillary racemes, 2-6 flowers and some times solitary in the female. The fruit is pendulous about 3 inches long and 2 inches wide with a yellowish-white, fleshy pericarp about ½ inch thick and a broadly ovoid seed 1¼ inches long closely enveloped by a brilliant scarlet, irregularly cut fleshy aril (mace). The

testa of the seed is dark brown, smooth and shining very hard and thick, and contains much endosperm. (Fig. 5.)

Fig. 5. *Myristica fragrans*, Houtt.
A branch showing leaves, flower and fruit

Trees bear all the year round and the fruit when ripe splits open and is gathered by means of a hook attached to a long stick. The pericarp is removed and then the mace and finally the nut. The mace and the nut are dried and prepared separately for the market while the fresh pericarp is used for preparation of nutmeg jelly.

History. Nutmeg and mace do not seem to have been known to the ancients. They were imported from India by the Arabians and passed on to Western countries. Masudi who visited India in 916-920 A.D. mentions nutmeg as a product of the islands of the Indian Archipelago. Petrus d'Ebulo describes the streets of Rome being fumigated with nutmeg and other aromatics for the entry of Emperor Henry VI for his coronation in 1191. The Portuguese and later the Dutch held the monopoly of the nutmeg and clove trade from 1512 to 1796. With the occupation of the Spice Islands by the English the cultivation of nutmeg spread into other countries until a destructive blight wiped out these new plantations in 1867.

Composition. Nutmeg contains about 35 per cent. soild fat and 7 to 13 per cent. volatile oil which is much similar to the oil from mace The constituents of this volatile oil are pinene, dipentene, myristicol, myristicin, myristinic acid and a phenol-like substance.

Uses. Nutmeg possesses carminative properties but in large doses it is a narcotic. It is used with advantage in mild cases of diarrhœa, flatulent colic and certain forms of dyspepsia. It is mostly employed to flavour food substances. The expressed fat and volatile oils have been used externally in chronic rheumatism.

NUX VOMICA—Nux Vomica

The dried ripe seeds of *Strychnos nux vomica,* Linn. (S. Goda-Kaduru ; T. Eddi, Kanchurai ; Skt. Chipita, Vishadruma.) a small tree usually come across in dry zone jungles of Ceylon constitutes the nux—vomica in medicine. It belongs to the family Loganiaceae and is distributed over India and Malay Archipelago. The tree has an erect trunk with a smooth yellowish grey bark and numerous opposite and cylindrical twigs which are dilated at the nodes. Leaves opposite, $2\frac{1}{2}$-4 inches long, ovate or broadly oval, rather unequal sided, 5-nerved glabrous and shining. Flowers numerous, greenish white on slender pedicels grouped in terminal peduncled paniculate cymes. Fruit a berry 1-$1\frac{3}{4}$ inches in diameter, orange red when ripe with a thin brittle pericarp and 1-6 seeds immersed in a pinkish grey plup. Seeds are button shaped, circular $\frac{3}{4}$ inch in diameter, much compressed, flat, slightly concave above and convex beneath, silver grey and shining with a dense covering of very fine adpressed hair radiating from the centre. (Fig. 6.)

History. Nuxvomica as a drug was unknown to the ancients. It was supposed to have been introduced into medicine by the Arabians. It was first known in Germany in the 16th century for Valerius Cordus wrote an accurate account of it in 1540. About 1640 the drug was found

Fig. 6. *Strychnos nux vomica*, Linn.

A. A branch with leaves and flowers. B. Fruit.

in English shops and its chief use was for poisoning dogs, cats, crows and ravens. The root bark, leaves and seeds were used in various ayurvedic preparations.

Composition. The drug contains mainly the alkaloids strichnine and brucine together with traces of vomicine, struxine in deteriorated seeds, χ-colubrine, α-colubrine and pseudo-strichnine. The leaves contain the alkaloid strychnicine.

Uses. The drug is largely used as a bitter stomachic and tonic. It stimulates the gastro-intestinal tract promoting peristalsis and hence given in constipation. It is valuable in cases of cardiac failure as it increases the blood pressure. In the ayurvedic system of medicine the different parts of the plant are used for the preparation of different

types of cures for intermittent fever, poisonous snake bites, dyspepsia, dysentery, cholera, diarrhœa, worms, hysteria, chronic constipation, nervous diseases, rheumatism and hydrophobia.

ILEUM CAJUPUTI—Oil of Cajuput

Cajuput oil is obtained by distillation from fresh leaves and twigs of *Melaleuca leucodendron,* Linn. (S. Lothsumbulu, Weradi-sumbulu T. Kajapute.) and other species of *Melaleuca.* The tree is abundant in the Indian Archipelago and Malayan peninsula and also in Northern Australia, Queensland and New South Wales. It belongs to the family Myrtaceae.

Melaleuca leucodendron is a fairly large tree with a thick spongy bark pealing off in layers and slender pendulous branches. Leaves silky, alternate, oval-lanceolate, tapering at both ends, 2-4 inches in length, 5-7 nerved. Flowers white in slender cylindrical spikes, 3-8 inches long, solitary or several together. Stamens very variable in colour ; white, greenish yellow, pink or purple.

History. The first account of the oil and the tree from which it is obtained was given by Rumphius who lived in East Indies for about 50 years and died at Amboyna in 1702. The oil was first in the hands of the Amsterdam druggists about 1727 under the name of *Oleum Wittnebianum.* In France and England it was not known until the beginning of the 19th century.

Composition. Cajuput oil contains chiefly cineole together with terpineol, acetate of terpineol, 1-pinene, and valeric, bytyric, benzoic and other aldehydes.

Uses. Cajuput oil is chiefly employed as a carminative and occasionally as a stimulant, antispasmodic and diaphoretic. Externally it is used as a rubefacient. In Ayurvedic medicine the bark of *M. leucodendron* is erroneously used for the bark of *Symplocos racemosa,* Roxb ; which is the correct " Lothsumbulu ".

OLEUM CHAULMOOGRAE—Chaulmoogra Oil

Chaulmoogra oil is obtained by expression from the seeds of *Taraktogenos kurzii,* King. a medium tree belonging to the family Flacourtiaceae. It is indigenous to the Malayan Peninsula and can be cultivated in Ceylon. The tree is 40-50 feet high with spreading more or less horizontal branches. Leaves sub-coriaceous, lanceolate or oblong lanceolate, 7-10 inches long and 2-3.5 inches broad, both surfaces shining. Flowers occur in axillary cymes from the smaller branches on thick peduncles. Fruit globular as large as an orange, the rind minutely granular, tawney-velvetty, the outer layer thick and fibrous and the inner layer thin with the seeds embedded in a pulp. (Fig. 7).

Fig. 7. *Taraktogenos kurzii,* King.
Branches with leaves and fruits

Composition. Chaulmoogra oil consists of glycerides of chaulmoogric and hydnocarpic acids together with smaller proportions of oleic and palmitic acids.

Uses. Chaulmoogra oil has the same properties as those of hydnocarpus oil and used similarly.

OLEUM CROTONIS—Croton Oil

Croton oil is obtained from the seeds of *Croton tiglium,* Linn. (S. Jayapala ; T. Naervalam ; Skt. Naepala, Jayapala) a small tree indigenous to the Malabar Coast and cultivated in Southern Asia and

China belonging to the family Euphorbiaceae. Leaves alternate, petiolate, ovate-cordate, serrate, 3-5 inches long, metallic green to bronze and orange in colour. Flowers are borne in terminal erect racemes, numerous male flowers above and a single apetalous female flower below. Fruit is a 3-celled capsule with a single oblong seed in each cell. (Fig. 8).

Fig. 8. *Croton tiglium*, Linn
Branches with leaves, male flowers, and fruits.

History. The plant was first described by Christoval Acosta in 1578 and subsequently by Rheede in 1679 and Rumphius in 1745.

Composition. Croton oil contains a violent vesicant substance called croton-resin which is a lactone of complex nature and glycerides of stearic, palmitic, myristic, lauric, valeric, butyric, acetic, formic, oleic, linolic and tiglic acids.

Uses. Croton oil is an extremely powerful cathartic and is given in very small doses. Externally it is a counter-irritant and vesicant.

In Ayurvedic medicine the seed is used along with other ingredients for preparation of curry for constipation, chronic rheumatism, gout, paralysis, chronic bronchitis, asthma, dropsy and apoplexy.

OLEUM HYDNOCARPI—Hydnocarpus Oil

This is the fatty oil obtained by cold expression from the fresh, ripe seeds of *Hydnocarpus wightiana* Blume, a tree indigenous to India. A pulsating arteriolitis may be found in *Hydnocarpus venenata*.

Fig. 9 *Hydnocarpus venenata*, Gaertn
Branches with leaves, flowers and young fruits.

Gaertn. (S. Makulu ; T. Makal) a native of Ceylon belonging to the family Flacourtiaceae (Bixaceae). The latter is a tree with a smooth whitish bark and pubescent young shoots. Leaves 4-6 inches long, lanceolate serrate, glabrous above and pubescent on veins beneath, petiolate. Flowers brownish white, male in small, crowded shortly peduncled axillary panicles while the females are solitary or two together densely pubescent. Fruit a globular berry 3/4-1 inch diameter, with a short blunt beak and densely covered with thick ferrugineous tomentum. (Fig. 9).

History. The inhabitants of Asia have been long acquainted with the seed of this tree which is used as a fish poison and the oil extracted as a remedy for various skin diseases.

Composition. Hydnocarpus oil consists of the glycerides of the fatty acid constituents, chaulmoogric and hydnocarpic acids along with oleic and palmitic acids.

Uses. Hydnocarpus oil is an effective agent for treatment of leprosy administered both orally and by intramuscular injections over a period of many months.

OLEUM RICINI—Castor Oil

Castor oil is obtained by expression from the seeds of *Ricinus communis*, Linn. (S. Endaru ; T. Amanakenna ; Skt. Eranda, Gandharvahasta.) a small tree or a half hardy annual herb belonging to the family Euphorbiaceae. It is a native of India and much cultivated throughout the tropics and in many temperate regions of the globe. Leaves alternate, variable in size and colour, petiolate, sub-peltate, palmately cut for about 3/4 of its depth into 7-11 lanceolate coarsely serrate segments. Flowers monoecious arranged in thick spicate panicles at first terminal later becoming lateral, male flowers on branched peduncles at the base and sessile female flowers at the upper part of the spike. Fruit is a three-celled capsule bearing 6 ovoid, shining, prettily mottled caruncled seeds.

History. Castor oil was known to the Egyptians, Greeks and Romans both medicinally and as an illuminant. It was used in Europe during the middle ages and re-introduced from the West Indies towards the end of the last century.

Composition. Castor oil consists chiefly of the glycerides of ricinoleic, isoricinoleic, dihydroxystearic and other acids.

Uses. Castor oil is employed as a mild and safe purgative. In Ayurvedic medicine parts of the plant are used for preparation of cures for rheumatism, constipation, tympanitis, lumbago, pleurodynia and sciatica.

OLEUM SANTALI—Oil of Sandal Wood

Sandal wood oil is obtained by distillation from the heart wood of *Santalum album*. Linn. (S. Sudu-handun ; T. Chandana kattai ; Skt. Chandana.) a small tree distributed over Southern India and the

Fig. 10. *Santalum album*, Linn
Branches with leaves, flowers and fruits

Malay Archipelago and cultivated in Ceylon. It belongs to the family Santalaceae. The tree has an erect trunk and numerous spreading branches. Leaves small, 1½-2½ inches long, opposite, ovate-elliptic

usually narrowed at both ends, membranous and paler beneath. Flowers small in many flowered panicles, at first yellowish gradually changing to a deep ferruginous purple colour. Fruit a black drupe resembling a cherry (FIG. 10).

History. Sandal wood was known in India earlier than the 5th century B. C. Cosmos Indicopleustes mentioned the wood having been brought to Ceylon from China towards the middle of the 6th century A. D. In Ceylon the oil was used as early as the 9th century for embalming the corpses of princes. In Europe, Constantinus Africanus and Ebn Serabi mention it in the 11th century.

Composition. Sandal wood oil contains santalol which is a mixture of two isomeric sesquiterpene alcohols, esters of santalol and an aldehyde santalol.

Uses. Oil of Sandal wood was formerly given in the treatment of subacute stages of cystitis and gonorrhœa but now it is mainly used as a perfume. In Ayurveda the wood is used for preparation of cures for gonorrhœa, biliousness, fever and dysentery.

OLEUM SESAMI—Sesame Oil (Gingelly Oil)

Sesame oil is obtained by expression from the seeds of *Sasamum indicum,* Linn. (S. Tala ; T Ellu ; Skt. Tila) an annual herb grown in most tropical countries including China, India and Ceylon. Its stem is erect 1–2 feet with long ascending branches from the base of the stem. Leaves opposite, the upper ones alternate, 1½-2½ inches long, lanceolate, entire, the lower ones often deeply cut at the base into two or more serrate segments, glabrous above, puberulous beneath with minute scaly hairs. Flowers large, axillary, solitary, pale pinkish purple on very short erect puberulous pedicles. Fruit a two-valved capsule dehiscing loculicidally with numerous oblong, slightly compressed, glabrous dark brown or black seeds.

History. Sesame seeds have been used by mankind since the earliest times. Pliny describes it as an article of export from Sind to Europe by way of the Red Sea. In the middle ages it was cultivated in Cyprus, Egypt and Sicily.

Composition. Sesame oil consists of the glycerides of oleic and linoleic acids with small proportions of stearic, palmitic and arachidic acids. It also contains sesamin and sesamol in small amounts.

Uses. Sesame oil has the same properties as those of olive oil and hence used in preparation of official liniments, plasters, ointments and soaps. In Ayurveda its leaves, roots, seeds and oil are used in preparation of cures for piles, constipation, amenorrhœa and dysentery.

OLEUM SINAPIS VOLATILE—Volatile Oil of Mustard

Volatile oil of mustard is obtained either synthetically or by distillation from the dried, ripe seeds of black mustard, *Brassica nigra*, (Linn.) Koch. (S. Kalu-aba : T. Kaduvu ; Skt. Sarsapa.) A small annual belonging to the family Cruciferae. It is indigenous to India and naturalized both in North and South America and can be cultivated in Ceylon. It has an erect stem with many spreading branches. Leaves petioled, variable in size, shape and lobation. Flowers small, numerous and very bright yellow. Fruit a siliqua, 1–2 inches long bearing dark reddish brown seeds.

History. Mustard was well known to the ancients. Diocletian mentioned it in A. D. 301 and it is possible that it may have been used as a condiment in the Eastern parts of the Roman Empire. About the 13th and 14th centuries it was much used in Europe especially during the winter along with salted meat.

Composition : Volatile oil of mustard contains allyl isothiocyanate and small amounts of allyl cyanide, carbon disulphide and probably traces of isomeric allyl thiocyanate.

Uses. The diluted oil is employed as a counter-irritant and rubefacient. It relieves referred pain as in pleurisy and pneumonia. In Ayurveda the seed is used for preparation of cures for paratitis, sciatica, paraplegia, gout, inflammatory swellings and urticaria.

OLEUM THEOBROMATIS—Oil of Theobroma

This is a solid fat obtained from the crushed and roasted seeds of *Theobroma cacao*, Linn. a small tree with a smooth greyish bark belonging to the family Sterculiaceae. It is a native of Brazil extending as far north as Mexico and extensively cultivated throughout the tropics. Tree is 16-18 feet high ; leaves alternate, stalked, 8-9 inchas long and 2½ inches wide, ovate-lanceolate, entire and veins prominent beneath. Flowers arise in clusters from the old wood of the branches and trunk. Fruit pendulous, solitary or two or three together, ovoid-oblong, 6-8 inches long, at first yellow afterwards red or purple containing 50-100 exalbuminous beam like seeds immersed in copious sweet buttery pulp.

History. Homberg in 1695 first prepared cacao butter from seed. Turbingen in 1735 and Geoffroy in 1741 called attention to its medical uses and recommended it for ailments such as haemorrhoids, &c.

Composition. Oil of theobroma contains mainly glycerides of stearic acid, palmitic and oleic acids with small quantities of linolic and other fatty acids.

Uses. Oil of theobroma is used as a base for preparation of suppositories, pessaries and bougies. It is also sometimes used as an ingredient in emollient ointments and the oil as a lubricant in massage.

PAPAINUM—Papain

Papain is a mixture of enzymes prepared from the juice of unripe fruit of *Carica papaya*, Linn. a tree belonging to the family Caricaceae. It is a native of South America and West Indies and much cultivated as plantations in other tropical regions including Ceylon. The tree is 10-20 feet tall stem cylindrical, mostly unbranched, bearing scars of fallen leaves on the trunk and carrying a crown of foliage with the fruits at the top. Leaves very large, long petioled lamina palmately 7-lobed, segments deeply lobed, oblong and acute. Flowers dioecious, male flowers in corymbose inflorescences while the females are more or less solitary and sessile. About 50 per cent. of the trees in a plantation are male and are removed when distinguishable. The tree grows best in loamy soils and is grown much as a catch crop in young rubber plantations and lands under re-afforestation. Trees are planted 10 feet apart and need no manuring. They bear in about 8 months and fruits are tappable when they are 3 months old. Fully grown fruits only are tapped by lancing the mature green fruits lightly on the surface by means of a bamboo splinter or stainless steel knife early morning before 10 a.m. The latex is collected in glass or porcelain vessels, pooled, coagulated by stirring vigorously with a wooden spoon, passed through a potato-squeezer and dried in the sun or well ventilated drier between 50°C and 55°C until crisp.

Composition. Papain is a complex mixture of proteolytic enzymes and peroxidases. Two of these enzymes have been named papain and chymo-papain.

Uses. Papain is used to assist protein digestion in the treatment of chronic dyspepsia and gastritis. It is administered in powders, pills, tablets or cachets.

PELLETIERINAE TANNAS—Pelletierine Tannate

Pelletierine tannate is a mixture of alkaloid tannates obtained from the bark of the root and stems of *Punica granatum*, Linn. (S. Delun ; T. Madalam palam ; Skt. Kuchaphala) a much cultivated shrub or small tree belonging to the family Punicaceae. It is generally considered a native of North-Western India, Southern Persia and Palestine

and to have been introduced to the Mediterranean countries, China and Western Asia in the distant past. The tree is 10-15 feet high often spiny. Leaves opposite, sometimes alternate, short stalked, 1-2 inches long, oblong-ovate or lanceolate tapering at both ends, smooth and shining. Flowers large solitary or 2 or 3 together in the axils of leaves, very shortly stalked, crimson to scarlet in colour. Fruit large 2½–3 inches diameter with a persistent calyx containing numerous seeds each covered by a pink juicy coating.

History. Pomegranate was known to mankind from very ancient times. References to it are in Mosaic writings, sculptures of Persepolis and Assyria and on ancient monuments of Egypt. It was probably introduced into Europe in about the 3rd Century B.C.

Composition. Pelletierine tannate consists of a mixture of tannates of the alkaloids, l-pelletierine, dl-pelletierine, pseudopelletierine and methyl pelletierine.

Uses. Pelletierine tannate is used as an anthelmintic with specific action on tapeworms. Pomegranate peel is an excellent astringent and in Ayurveda it is used as a remedy in chronic dysentery and diarrhœa. The flowers are used along with human breast milk for certain eye ailments.

PICROTOXINUM—Picrotoxin

Picrotoxin is a principal obtained from the dried ripe fruits of *Anamirta paniculata*, Colebr. (S. Titta-wel ; Skt. Garalaphala.) a large woody twiner indigenous to East India and Malay Archipelago and rather common in Ceylon in the moist low-country up to an elevation of 2,000 feet. It belongs to the family Menispermaceae. Leaves alternate, on long stalks, broadly ovate, subordinate at base, 3-6 inches long, glabrous above, paler and with very small tufts of hair in the axils of veins beneath. Flowers small, dioecious, arranged in pendulous, pale greenish-yellow, sweet scented, compound racemes springing from the old wood. Fruit usually two, rounded ovoid drupes, on thickened branches of enlarged gynophore, ½ inch long, smooth and black (Fig. 11).

History. Ruellius in 1536 mentions of little berries found in shops under the name of " Cocci Orientis " which when scattered on water stupify fish. Gerarde says that it is well known in England (1597) as Cocculus Indicus and used for destroying vermin and poisoning fish. The celebrated Italian physician Battista Codronchi advocated its use in medicine in the 16th century.

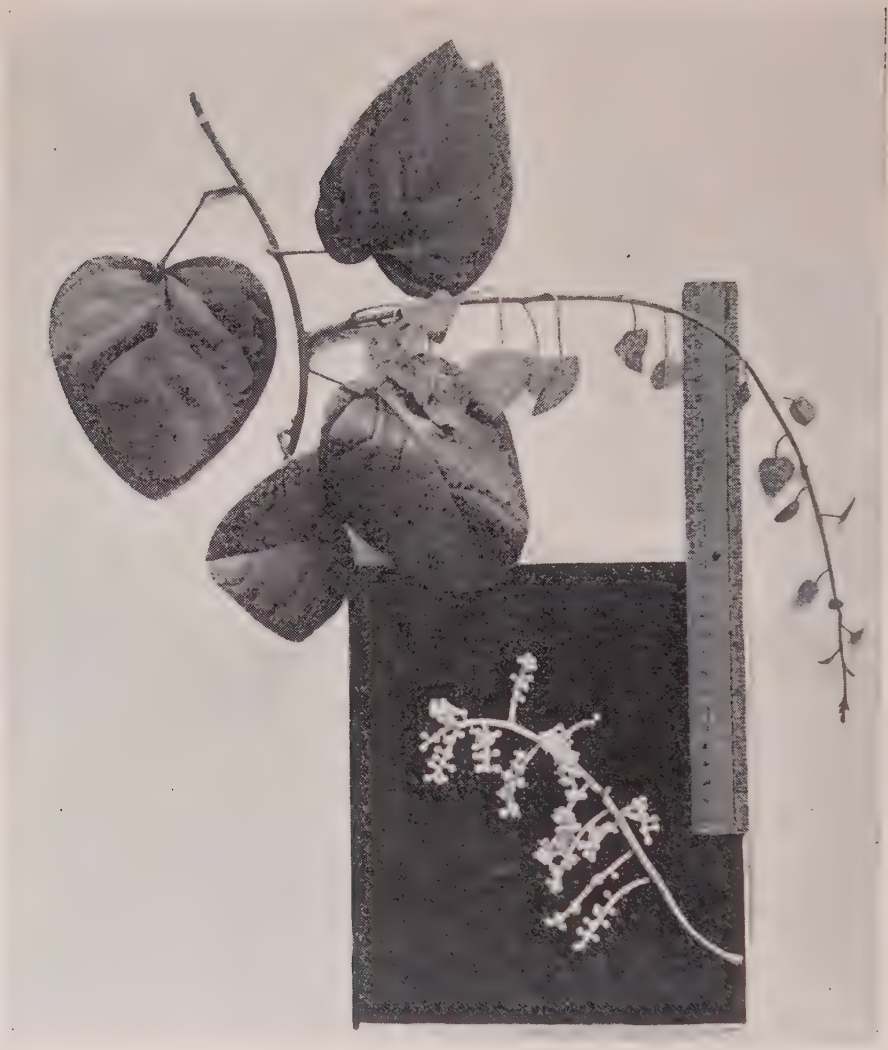


Fig. 11. *Anamirta paniculata*, Colebr
A branch with mature and young leaves and also a part of the inflorescence

Composition. The neutral principal, picrotoxin, is extracted from the powdered seed and crystallised as an odourless, intensely bitter powder.

Uses. Picrotoxin is a powerful respiratory stimulant and convulsive agent. It is given as an intravenous injection in the treatment of poisoning by barbiturates and morphine.

PIPER NIGRUM—Black Pepper

Black pepper consists of the dried unripe fruits of *Piper nigrum*, Linn. (S. Gammiris ; T. Milagu ; Skt. Maricha) a perennial climbing plant belonging to the family Piperaceae. The ripe fruits deprived of the outer pericarp forms the white pepper of commerce. The plant is indigenous to South India and cultivated in other countries such as Java, Sumatra, Borneo, Malay peninsula, Siam, Philippines, West Indies and Ceylon. The stems are jointed whence adventitious roots which attach themselves to neighbouring supports arise and dichotomously branch. Leaves alternate 4–6 inches long, stalked, ovate, entire, smooth on both surfaces, paler beneath with 5–7 prominent veins. Flowers unisexual, monoecious, sometimes hermaphrodite, sessile in slender pendulous spadices 3–6 inches long, coming off opposite leaves. Fruit a berry on slender pendulous spikes, at first green, then red and yellow when ripe, with fleshy pericarp and solitary seed.

History. Pepper is one of the earliest spices known to man. About the 4th century B. C. Theophrastus noticed the existence of two types of pepper. Dioscorides and Pliny mention pepper as a product of India. Cosmas Indicopleustes in 540 A. D. described the pepper plant from Malabar Coast as a vine-like climbing plant sticking close to high trees. Among the Europeans the first to describe the plant with a certain amount of accuracy was Benjamin of Tudela who visited the Malabar Coast in 1166 A. D. In Europe pepper was held in high esteem. When Rome was besieged by Alaric, king of the Goths in 408 A. D. the ransom demanded from the city included, besides gold and silver, 3,000 pounds of pepper. The high cost of this condiment incited the Portuguese to seek a sea-passage to India and after the discovery of this passage the crown of Portugal held the monopoly of the pepper trade until as late as the 18th century.

Composition. Pepper contains piperine, a crystalline alkaloid, a volatile oil consisting entirely of sesquiterpenes, a pungent green resin, chavicin which is a compound of peperidine and chavicinic acid in addition to a large quantity of starch.

Uses. Black pepper stimulates the production of gastric secretion and improves the appetite. It is also a diuretic. In Ayurveda it is used for preparation of medicines to cure dyspepsia, cough, gonorrhœa flatulence, intermittent fever and hæmorrhoids.

PYRETHRI FLOS—Pyrethrum Flower

This consists of the dried flower heads of *Chrysanthemum cinerariae-folium*, Vis., a herbaceous perennial belonging to the family Compositae. It is a native of Dalmatia, Herzegovina and Montenegro

and cultivated in Japan, California, Spain, Italy, Switzerland, &c. The plant is glaucous and tufted. Stems slender, erect, one-headed, 12–15 inches in height. Leaves pinnatisect ; segments long, narrow, pinnatifid, rather distant and spreading. Flower heads 1½ inches across, rays white, 3 toothed at the tip, disc yellow, involucral bracts rounded with white tips.

It thrives best in well drained sandy soil and also red laterite loams. The seed germinates in 10–15 days. Seedlings are transplanted when they are 4–5 inches high on ridges 7–12 inches apart in rows 1–2 feet apart. Plants flower within one year. First crop is gathered on the third year after planting and the harvest continues 3–4 years. Flower heads are gathered when they are three-fourth open and the average yield is about 450 pounds per acre.

Composition. Pyrethrum flower contains two active principals pyrethrin I and pyrethrin II which are esters of a keto-alcohol called pyrethrolone and chrysanthemum monocarboxylic and dicaboxylic acids.

Uses. Pyrethrum flower is used both as a dust and in liquid form principally as an insecticide and an insect repellent. A preparation of the extract in a non-inflammable and non-oily base is used as a spray from aircraft to kill insect vectors preventing the transmission of insect borne diseases.

QUASSIA—Quassia

Quassia consists of the dried stem-wood of *Picraena excelsa,* Lindl, a moderate sized tree belonging to the family Simarubaceae and indigenous to Jamaica. A suitable substitute which can be grown in Ceylon is found in *Quassia amara,* Linn. a large shrub or small tree indigenous to Panama, Venezuela, Guiana and Northern Brazil. The tree is about 15–18 feet in height, leaves large, alternate, pinnate ; leaflets usually 5, sessile, mostly obovate to oblong-lanceolate, 3½–6 inches long, long attenuate to the base, rachis laminate, deep green above and paler beneath. Flowers crimson, in long narrow racemes. Fruit oval or obovoid drupe, ⅓–½ inch long and black in colour (Fig. 12.)

History. Quassia wood was introduced to Europe about the middle of the last century and it was the wood of *Quassia amara,* Linn. then, which subsequently was superseded by *Picraena excelsa,* Lindl. The latter was obtainable in larger quantity and hence preferred. However the wood of *Q. amara* is still used in France and Germany.

Composition. Quassia (wood of *Q. amara*) contains the bitter principals quassin and neo-quassin both of which are isomeric with picrasmin the principal contained in wood of *P. excelsa* which in addition contains crystals of calcium oxalate.

Fig. 12. *Quassia amara*, Linn.

Branches with leaves, bright crimson flowers in racemes and clusters of black fruit.

Uses. Quassia is used as a bitter tonic and also for preparation of horticultural insecticides. An infusion of it is used as an enema for the expulsion of threadworms.

RAUWOLFIA—Rauwolfia

Rauwolfia consists of the dried roots of *Rauwolfia serpentina*, Benth. (S. Eka-weriya, Rat-ekaweriya ; Skt. Sarpagandha.) a large climbing or twining shrub growing in India, Burma, Siam and Java. It belongs to the family Apocynaceae. In Ceylon the plant is a small herbaceous semi-woody perennial 1–2 feet in height commonly found growing in shady moist regions up to an elevation of 2,000 feet. Leaves in whorls of 3, 4-5 inches long, lanceolate, tapering at both ends, undulate, glabrous, thin, petiole short and obscure. Flowers in close, irregular, corymbose cymes on long erect peduncles, white or bright red in colour. Ripe fruit is a 2-carpillary slightly conuate blackish-purple berry, each segment containing a single albuminous seed.

Composition. Rauwolfia contains the alkaloids ajmaline, ajmalinine, serpentine, serpentinine, rauwolfine and rauwolscine, a phytosterol, fatty acids, mixture of unsaturated alcohols, dextrose, sucrose, fumaric acid and a fluorescent substance.

Uses. The drug has a hypnotic action on the nervous system resembling twilight sleep and is widely used in India for treatment of insomnia and certain types of insanity. It also produces a fall in the blood pressure and has been used in the treatment of hyperpiesis.

SENNA FOLIUM—Senna Leaf

Senna leaf consists of the dried leaflets of *Cassia acutifolia*, Delile. known as Alexandrian senna and of *Cassia angustifolia*, Vahl. called Tinnevelly senna, both shrubs the former indigenous to and cultivated in the middle and upper Nile and the latter cultivated largely in Southern India. Both shrubs belonging to the family Leguminosae and can be cultivated in Ceylon. *C. acutifolia*, Delile. Small shrub 2 feet high ; leaves alternate, stalked, petiole without a gland, paripinnate, leaflets opposite in 4–5 pairs, very shortly stalked, lanceolate or oval lanceolate, acute at both ends and mucronate at the apex. Flowers medium, arranged in few flowered, erect, axillary racemes. Pod broadly oblong about 2 inches long, $\frac{7}{8}$ inch broad, tapering below and about 6 seeds to the pod. *C. angustifolia*, Vahl. Small shrub similar to above in the characters of the stem and leaves. Leaflets 5–8 pairs, narrowly lanceolate or obovate-lanceolate, entire bright green above, glaucous on the under surface. Flowers similar to above. Pod oblong over 2 inches long, $\frac{5}{8}$–$\frac{3}{4}$ inch broad and about 8 seeds to the pod.

History. Knowledge of senna cannot be traced back earlier than and isorhamnetin occurring both free as well as glucosides ; Europe is due to the Arabian physicians. Isaac Judaeus about 850–900 A. D. mentions senna as brought from Mecca.

Composition. Senna leaf contains rhein, aloe-emodin, kaempferin and isorhamnetin occurring both free as well as glucosides ; kaempferol, myricyl alcohol and phytosterin are also present along with mucilage, calcium oxalate, resin and an amorphous glucoside.

Uses. Senna leaf is administered as an infusion and forms one of the most useful purgatives in cases of habitual constipation and in the treatment of haemorrhoids. It is a suitable laxative for children.

The dried ripe fruits of these plants form the *senna fruit* which too has almost the same uses. In Ayurveda the leaflets of *Cassia obovata,* Collad. called (S. Senaha kola) are used as a suitable substitute and much used as a purgative.

STRAMONIUM—Stramonium

Stramonium consists of the dried leaves and flower tops of *Datura stramonium*, Linn. and *Datura tatula,* Linn. annuals belonging to the family Solanaceae. The three species commonly used in Ayurvedic medicine are *D. fastuosa,* Willd. (S. Kalu-attana ; T. Venumattai ; Skt. Krisna dattura), *D. alba,* Rumph. (D. stramonium, Linn.) (S. Ela attana ; T. Umatai ; Skt. Dattura) and *D. suaveolens,* H. & B. (S. Tun-bo-attana).

D. stramonium, Linn. a weedy annual about 3 feet in height, stem erect, green, thick, succulent dividing at a short distance from the ground into 2 or 3 spreading branches which again divide dichotomously forming a large bushy herb. Leaves placed singly on one side of each bifurcation, pale green, unequal in size, the lowest ones to largest, 8–9 inches long, ovate, margin undulated and deeply dented with irregular incisions forming unequal spreading teeth, base unequal one side running along the top of the petiole for a short distance, apex acuminate, dull green, paler beneath. Flowers solitary in the forks, shortly stalked, tubular-funnel shaped, 3-4 inches long. Fruit is an ovoid, spiny, 4-celled capsule with numerous seeds.

This occurs as a roadside weed in Ceylon. *D. tatula,* Linn. is very much similar to above excepting the stems and outside of the corolla being purple in colour.

Composition. Stramonium contains chiefly the alkaloid hyoscyamine associated with atropine and hyoscine.

Uses. The drug is chiefly used to relieve the spasm of the bronchioles in asthma. In Ayurveda the different parts of the species mentioned above are used for preparation of medicines to cure chronic cough,

asthma, fever, skin diseases, boils, itch, worms, insanity, rheumatism, tooth-ache, lumbago, ophthalmia, ear-ache, gonorrhœa and hydrophobia.

STROPHANTHUS—Strophanthus

Strophanthus consists of the dried, ripe seeds freed from the awns of *Strophanthus kombe,* Olio. a climbing plant belonging to the family Apocynaceae and indigenous to tropical East Africa. Suitable substitutes are found in *Strophanthus sarmentosus,* D.C. and *Strophanthus hispidus*, D.C. both of which are indigenous to Sierra Leone and lower Congo and can be cultivated in Ceylon in the moist mid-country. *S. sarmentosus* is a large shrubby climber ; leaves opposite, lanceolate to ovate-lanceolate tapering towards the base and apex acuminate, 2-2½ inches long, ¾-1 3/8 inches broad, dark green above, paler and yellowish green beneath.

S. hispidus, D.C. is also a woody climber, stem and leaves covered with bristly hair, leaves opposite, sessile, oval, apex abruptly acute, 6-6½ inches long, 3-3½ inches broad, bright waxy green above, paler beneath, both surfaces covered with bristly hair.

Composition. Strophanthus contains a mixture of glycosides and fixed oil. The glycosides are mainly cymarin, k-strophanthin-β, k-strophanthoside, etc. It also contains kombic acid, choline and trigonelline.

Uses. Strophanthus is used in place of digitalis in tincture form when a rapid cardiac effect is required. It raises the blood pressure and is an efficient diuretic. It is not cumulative and rapidly excreted and hence preferred to digitalis when this remedy has failed or disagreed.

TAMARINDUS—Tamarind

Tamarind consists of the fruits of *Tamarindus indica*, Linn. (S. Siyambala ; T. Puli-maram ; Skt. Tiutridee) a large tree much cultivated in India, Africa, West Indies, Pacific Islands and Ceylon. It belongs to the family Leguminosae. Leaves alternate, abruptly pinnate, 3-4 inches long ; leaflets 8-16 pairs, opposite, sessile, oblong, unequal at the base. Flowers small arranged in few flowered axillary or terminal racemes. Fruit a pendulous, slightly compressed fleshy legume, 3-6 inches long, somewhat curved, pale chocolate brown, epicarp thin brittle, filled with soft firm pulp surrounding the seed cavities. Seed somewhat flattened, polished, smooth purplish brown and exalbuminous.

History. Tamarind was not known to the ancient Greeks, Romans and even to the Egyptians. The earliest mention of it appears in the ancient Sanskrit writings and was considered by the Arabian authors Matthaeus Platearius and Saladinus as fruit of a wild palm growing in India. A correct description of the tree was given by Garcia d'Orta in about 1566.

Composition. Tamarind contains tartaric acid, potassium acid tartate and 25–40 per cent. invert sugar.

Uses. Tamarind is used as a mild laxative. In Ayurveda the leaf of the tree is used in dysentery and as a poultice applied to inflammatory swellings and the fruit pulp as a laxative.

TONCO SEMEN—Tonka Bean

Tonka beans are the seeds of two species *Dipteryx*, large trees of considerable size belonging to the family Leguminosae. The two species are *Dipteryx odorata*, Willd. a native of Guiana and *Dipteryx oppositifolia*, Willd. from Brazil.

D. odorata, Willd. can be grown in Ceylon. It is a large tree with much spreading branches ; leaves pinnate carrying 4 large leaflets placed alternately, the rachis flattened, terminating in a small flap. Pinnae lanceolate, 6 inches long and 2½ inches broad. Flowers purplish pink, borne at the ends of branches in paniculate racemes. Fruit is a single seeded fibrous drupe.

Composition. Tonka beans contain as much as 3 per cent. coumarin to which the seed owes its fragrance. 45 per cent. fixed oils and proteins.

Uses. Tincture of Tonka is used by confectioners as a substitute for vanilla. It is widely used in perfumery and for flavouring tobacco and snuff.

ZINGIBER—Ginger

Ginger consists of the sun dried peeled rhizome of *zingiber officinale*, Roscoe. (S. Inguru, Siddinguru ; T. Shukku, Inji ; Skt. Adraka, Sunti.) a perennial herb indigenous to Asia but cultivated in the West Indies, Africa, India, Ceylon and other tropical countries. It belongs to the family Zingiberaceae. The plant has a large, solid, tough, many-jointed horizontal rhizome ringed with leaf scars. Leaves alternate, distichous,

smooth, pale green. 8-12 inches long, linear-lanceolate, tapering at both ends, shortly petioled with a prominent midrib beneath. Flowering stems 6-12 inches high, erect, surrounded by a few blunt leaf sheaths. Flowers few, small, sessile each surrounded by a thin convolute bract placed at the axils of larger concave bracts which in turn are closely placed at the summit of the flowering stem.

History. Ginger was known in India from the remotest times and used as a spice by the ancient Greeks and Romans. In England ginger must have been known before the Norman Conquest as it is mentioned in the Anglo-Saxon leech-books of the 11th century. Marco Polo speaks of having observed the ginger plant in China and India (1280-1290). Ginger was introduced to America by Francisco de Mendoca who took it from East Indies to New Spain.

Composition. Ginger contains 1 to 2 per cent. of volatile oil which is made up of a mixture of camphene, phellandrene, zingiberene, zingiberol, eucalyptol, citral, borneol, methylheptenone, nonyl alcohol, linalool and esters of acetic and caprylic acids. The pungency is due to gingerol and also contains shogaol, resin and much starch.

Uses. Ginger is used largely as a condiment and medicinally as a carminative and aromatic stimulant. In Ayurveda it is used for preparation of cures for dyspepsia, diarrhoea, flatulence, colic, vomiting, affections of the throat, head and chest, piles, rheumatism, urticaria, dropsy, cough, catarrh, spasms and other painful affections of the stomach and bowels and fever.

(*Received 6 February 1957*)

(CONCLUDED)

REFERENCES

ALLPORT, NOEL L. The Chemistry and Pharmacy of Vegetable Drugs, 1943.

ATTYGALLE, J. Sinhalese Materia Medica. 1917.

The British Pharmaceutical Codex, 1934, 1949 and supplement 1952.

CHANDRASENA, J. P. C.—The Chemistry and Pharmacology of Ceylon and Indian Medicinal Plants 1935.

CHARAVANAPAVAN, C.—*Studies in the Preparation, Properties and Assay of Commercial Papain*—Tropical Agriculturist, 1945, Vol. C1, pp. 72-76.

DASTER, J. F —Medicinal Plants of India and Pakistan, 1953.

DYMOCK, W.—Pharmacographia India—A History of the Principal Drugs of Vegetable Origin met with in British India, Vols. 1-111, 1890-1893.

DYMOCK, W.—The Vegetable Materia Medica of Western India, 1884.

FLUCKIGER, F. A. and HANBURY, D.—Pharmacographia, A History of the Principal Drugs of Vegetable Origin met with in Great Britain and British India, 1874.

GILDEMEISTER, E. and Fr HOFFMAN—The Volatile Oils: translation by E. Kremers, 1900.

GREENISH, H. G.—A Text Book of Pharmacognosy, 1933.

GREENISH, H. G.—A Text Book of Materia Medica, 1909.

GUNAWARDANA, G. W. GABRIEL—Medicinal Plants of Ceylon and Sinhalese Medicines in English, 1917.

HENRY, T. A.—The Plant Alkaloids, 4th Edition, 1949.

KING, G.—Flora of Malayan Peninsula—1889-1893.

LEWIS, F.—The Vegetable Products of Ceylon, 1934.

MAC NAIR, J. P.—*Spices and Condiments*—Leaflet No. 15. Field Museum of Natural History, Dept. of Botany, Chicago, 1930.

PARSONS, T. H.—*A list of Medicinal Herbs, Indigenous and Exotic, that can be cultivated in Ceylon*—Bulletin No. 91, Department of Agriculture, Ceylon, 1937.

STOCKDALE, F. A.—*The Cultivation of Papaya and the Preparation of Papain.*—Tropical Agriculturist, 1927, Vol. LXVIII, pp. 3-8.

TRIMEN, H.—A Handbook of the Flora of Ceylon and supplement by A. H. G. Alston, Parts 1-6, 1893-1931.

TRIMAN, H. and BENTLEY.—Medicinal Plants, Vols. 1-2.

A COMBINED AUTOMATIC SEED DRILL, FERTILIZER DISTRIBUTOR AND WEEDER FOR MUDLAND PADDY

By C. R. Karunaratne

(Agricultural Officer—Department of Agriculture, Ceylon.)

AUTOMATIC bullock and tractor operated seed drills are available for seeding highland crops and paddy under dry conditions. No automatic seeders have hitherto been designed for seeding paddy under puddled conditions in any of the rice growing countries.

Recently, row planting of paddy as done in Japan has been introduced quite successfully and this method of transplanting paddy is becoming popular. Further progress in cultural methods has been effected by introducing row dibbling in puddled paddy fields. According to the trials conducted by the Botanist there appears to be no significant difference in yield between dibbled and transplanted paddy. Hand dibbling of seeds in puddled fields is, however, a tedious operation.

After a series of tests, the writer perfected a simple convertible automatic seed drill for sowing paddy in puddled land and for distributing fertilizers in rows. The machine can be used or adapted to work as a weeder or intercultivator for paddy thus serving a triple purpose. The machine drills both germinated or ungerminated paddy and can be worked on any soil, under dry or puddled conditions, in heavy or light soil. This drill is a modification of the automatic machine the writer had designed about an year ago for seeding highland crops.

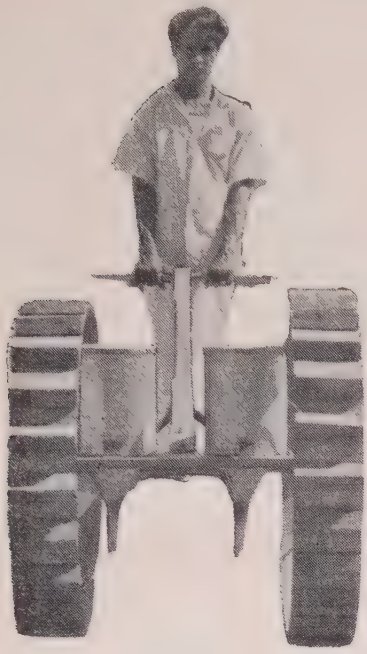
The machine drills the seed in ten 10 in. rows, the seeds being dropped at an average of 18 seeds per foot or 40 lb. (28 measures) per acre. The seed rate can be varied from 29 to 46 lb. (20-32 measures) per acre by shifting the seed containers forwards or backwards in relation to the position of the opening on the rubber facing and the opening on the guard on the seed rollers. The seed rate is reduced when

the seed containers are shifted forwards and is increased when they are shifted backwards. Drills to sow 4 rows or 3 rows at a time spaced at 10 inches for larger *liyaddes* and another to sow two rows at a time for narrow *liyaddes* have been designed. All that is necessary is to fill the seed container and draw the drill along the *liyadde ;* the seeds drop automatically through the seed spouts in well-defined rows at an average seed rate of 40 pounds (28 measures) per acre. One man can sow about 3 acres per day.

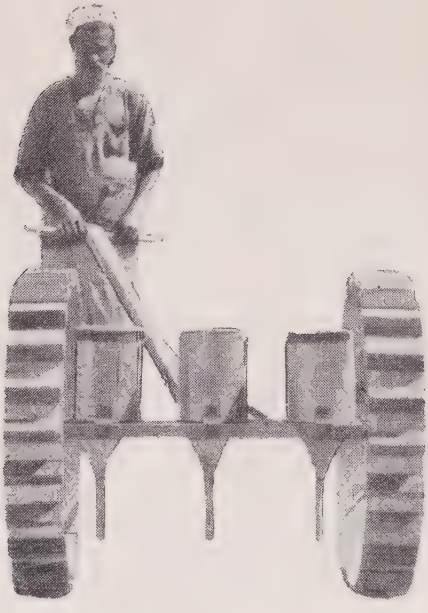
DESCRIPTION

Seed Rollers. The drill consists of seed boxes or containers of thin 26-gauge galvanised zinc hinged on to a wooden plank one inch thick, eight inches wide and 30 inches long, forming the frame for a three-row drill. Openings are provided on the plank to accommodate the wooden seed rollers so that these project into the bottom of the seed boxes. The seed rollers 3 inches in diameter and $1\frac{3}{4}$ inches wide are spaced 10 inches apart from centre to centre and securely mounted on the tubular drive shaft. Each roller is recessed with 10 holes—each $\frac{1}{2}$ inch long, $\frac{3}{8}$ inch wide and $\frac{1}{8}$ inch deep round the central circumference. The full circumference of the roller, excluding the holes, is enveloped with a thin piece of zinc serving as a collar to reduce wear and tear on the roller. The seed rollers are securely mounted on a half-inch tubular drive shaft with a nail driven through each roller into the shaft. The wooden plank is grooved at the bottom to accommodate the tubular drive shaft which is fixed under the plank by means of two iron brackets held in position by four bolts and nuts. The seed rollers project above the openings provided on the plank and also into the bottom of the seed containers.

Seed Containers. The seed containers made of 26-gauge galvanised zinc are cylindrical in shape, $8\frac{1}{2}$ inches high and $6\frac{1}{2}$ inches in diameter. A conical shaped piece of zinc with a $1\frac{3}{4}$ inch hole at the bottom is fixed inside each container to ensure a regular and uninterrupted flow of seed to the seed rollers. The bottom of each seed container is provided with an opening two and one-fourth inches wide and three inches long to accommodate the portion of the seed roller that projects into the seed container. The outer surface of the bottom of each container is fitted with a thick rubber facing made from a discarded lorry tube and is provided with a slot or hole $\frac{3}{4}$ inch wide and $1\frac{1}{4}$ inches long, sitting just above the seed roller and serves as a cushion to prevent the seed from cracking and being otherwise damaged. The



Two-row Seeder or Fertilizer-distributor



Three-row Seeder or Fertilizer-distributor

slits are provided on the rubber facing on either side of the slot to allow for the portion of the seed roller that projects inside the container. The seed container is hinged on the plank on one side and held in position by a lug on the opposite side so that it can be tilted for purpose of examination or for cleaning the rollers. A sliding shovel-shaped piece of zinc of thicker gauge inserted at the bottom of the cone, inside the container, serves as a throttle to cut off the flow of seed to the rollers when the machine is to be transported or when the end of the *liyadde* is reached. It also regulates the distribution of fertilizers when used for that purpose.

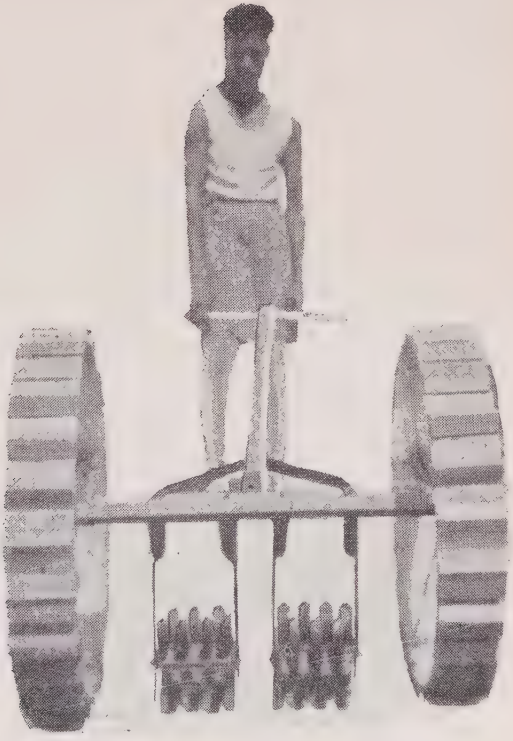
Collars and Seed Collecting Boxes. A piece of zinc three inches by four inches by one-fourth inch mounted about one-sixteenth inch above each roller is fixed to the plank and to two semi-circular collars on either side of each roller to serve as a shield to prevent friction and wear and tear of the rubber facing as the roller rotates. This shield is provided with a slot 2 inches $\times$ $\frac{1}{2}$ inch, sitting immediately over the holes of the roller. The seed picked up by the seed rollers in their line of travel are dropped into the funnel shaped seed collecting boxes, made of thin gauge galvanised zinc, enveloping the entire seed rollers and securely screwed on to the bottom of the plank, immediately below the rollers. The seed spout attached to each seed box can be lengthened if necessary by attaching an extra piece of galvanised tubing or a piece of rubber tube.

Wheels. The two wheels are of thick, 18 gauge galvanised zinc, 28 inches in diameter and five inches wide fitted with 24 wooden triangular lugs. This gives additional support and prevents the machine from sinking. For a three-row drill, spaced ten inches apart, the wheels are set at 30 inch centres. The wheels are coupled on to a half inch tubular pipe. One wheel drives the shaft. This is done by inserting a split pin through the bush or collar of the wheel into the drive shaft.

Draft Pole. A light wooden beam or draft pole one and a half by two inches and six feet long with a two foot grip at one end is securely fixed to the plank obliquely or at an angle with an iron semicircular bracket so that the end of the beam is in line with one wheel. This arrangement enables the operator to walk along the wheel tract and thus avoid the area sown being trampled on. The machine can easily be transported by dismantling the two wheels and if necessary the draft pole.

Above. Three-row Seeder dismantled for easy transport

Right. Double Weeder



Virtues of the machine include the following :—

1. Lightness : it weighs 47 lb.

2. Accurate metering of seed.

3. Elimination of markers ; the tracks left by the wheels serve as indicators for the return rows.

4. Absence of seed damage.

5. Economy in seed.

6. Versatility : the machine serves as seed drill, fertilizer distributor and weeder.

SEED AND SOIL CONDITIONS FOR DRILLING

When germinated seed is to be drilled it would be preferable to use partially germinated seed which has been dried in the shade. The seed may be soaked for twenty-four hours and heaped under pressure for two nights and thereafter spread out in the shade to dry.

Prior to drilling, the water in the field should be drained out the previous evening to ensure even and well defined rows. The rate of working is limited solely by the speed at which the operator could work in a straight line. On an average three acres could be sown per day.

DISCUSSION

As a paddy seed drill for seeding under puddled conditions this machine has great possibilities. Apart from the fact that it could be constructed by village blacksmiths and carpenters from materials easily available, there is a considerable saving in seed paddy and an appreciable reduction in cost of production. Broadcasting results in uneven distribution of seeds, wastage in valuable seed and renders weeding a very laborious and expensive item of work. On an average about twenty women are required to weed an acre of broadcast field. In densly populated areas and where the holdings are comparatively small, transplanting or weeding broadcast fields is commonly practised, but in sparsely populated areas and where the holdings are larger, weeding is the exception rather than the rule.

Uncertain weather conditions in the dry zone and the difficulty of raising nurseries under minor and major irrigation schemes owing to the water issues preclude extensive transplanting. The improved

Weeding row-sown paddy with the Single Weeder

Weeding between rows with the Double Weeder

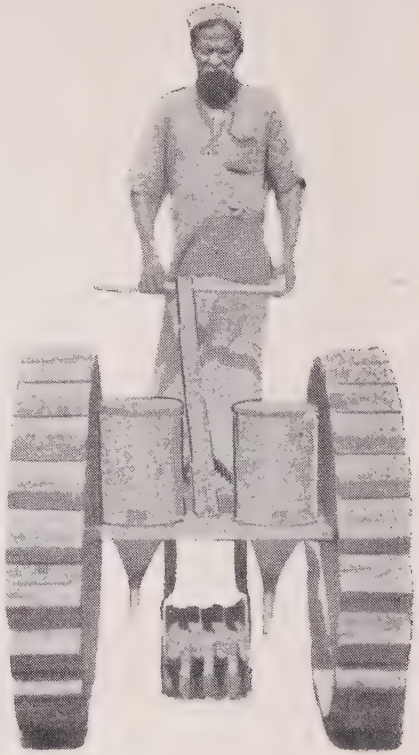
method of drilling the seed in rows, apart from effecting an appreciable saving in seed paddy, simplifies the task of weeding and reduces the cultivation cost per acre by about hundred rupees in the case of transplanting and by about fifty rupees in the case of broadcasting.

Operation	*Transplanting ordinary method*	*Row transplanting Jap method*	*Broadcasting*	*Drilling*
1. Preparation of nurseries	2 men 6·00	6 men 18·00	—	—
2. Manure for nurseries	—	5·00	—	—
3. Uprooting seedlings	10 women 20·00	2 women 4·00	—	—
4. Transplanting	30 women 60·00	10 women 20·00	—	—
5. Seed paddy	1 bushel 12·00	½ bushel 6·00	2 bushels 24·00	28 measures 10·50
6. Weeding	—	—	20 women 40·00	—
7. Intercultivating	—	2 men 6·00	2 men 6·00	2 men 6·00
8. Drilling ..	—	—	—	½ man 1·50
Total ..	98·00	59·00	70·00	18·00

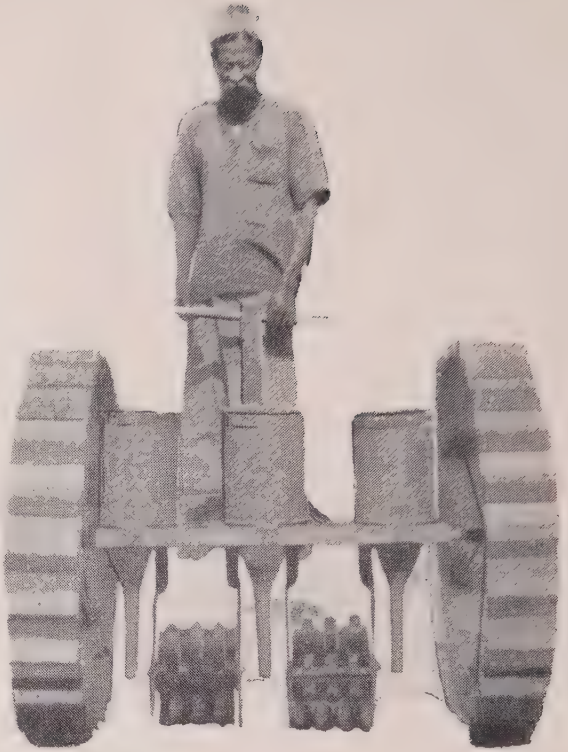
As a Fertilizer Distributor. The machine can be used to distribute fertilizers along the rows without any difficulty by filling the seed containers with the fertilizer. The quantity to be spread can be regulated by means of the throttle arrangement. When the throttle is quarter opened approximately 120 pounds can be distributed per acre and when it is half opened approximately 240 pounds can be distributed per acre.

In order to prevent possible damage to the rubber facing, the seed containers and the rollers should be washed thoroughly immediately after the application of fertilizers.

Adapted as a Weeder. This drill can very easily be adapted to work as a weeder by fixing the weeder attachments to the bottom of the plank of the drill by means of bolts and nuts. The lower section of each of the two arms supporting each weeder has a groove cut to raise or lower the position of the weeder as may be desired for deep or shallow work. The weeder has a clearance of 14 inches so that the



Combined Two-row Seeder and Single Weeder



Combined Three-row Seeder and Double Weeder

implement can be used at different stages of the development of the crop. When the drill is to be used as a weeder, the draft pole should be adjusted so that it is at right angles on the bracket fixed to the draft pole and the frame.

A two-row drill can carry one weeder ; a three-row drill carries two weeders. The two broad, lugged wheels serve to bury the weeds in the mud. Thus a two-row drill operates on three rows of paddy and a three-row drill on four rows of paddy. The strain on the operator working a single row Japanese weeder is much more than the weeder operating three or four rows at a time with a proportionately larger out-turn of work.

A Paddy Weeder. Instead of using the drill with the weeder attachment for weeding between rows of paddy it is preferable to fix the weeder attachments to a separate plank and a shaft and thus avoid unnecessary splashing of mud on the seed containers and seed boxes. All that is necessary is to fix a half-inch galvanised tube for the drive shaft on a plank $1\frac{1}{2}$ in. $\times$ 8 in. and a draft pole. For a single weeder attachment, a plank $1\frac{1}{2}$ in. $\times$ 8 in. $\times$ 18 in. and a half inch tube $25\frac{1}{2}$ in. long will be required. For a double weeder attachment, the length of the plank should be $27\frac{1}{2}$ in. and the tube 36 in. long. The wheels used for the seed drill can be slipped into the tubular axle, thus extra wheels are not required. Each weeder section is six inches wide fixed on two Y shaped supports. The lower section of each support is provided with a long slit for purpose of lowering and raising the weeder section as may be necessary and regulating the depth of work. The supports are fixed on to the bottom of the plank by means of bolts and nuts. The clearance space of 14 inches has been provided between the axle and the weeder so that inter-row weeding operations can be carried out during various stages of the development of the crop. A double weeder weighs 51 lb. and a single weeder 38 lb. The implement can be transported on the shoulder of the cultivator with the two wheels removed if necessary. On an average about $1\frac{1}{2}$ to 2 acres can be weeded per day by one man.

ACKNOWLEDGMENTS

The writer gratefully thanks Mr. A. J. Wijesinghe, Conductor, Cacao Station, Kundasale, for supervising the construction of the machine, Mr. K. D. S. S. Nanayakkara for assistance in field tests, and Messrs. Devendra and Alvahanhamy, blacksmiths.

(Received 22 January 1957)

METEOROLOGICAL REPORT

Summary for October-December, 1956

A low pressure area at the beginning of the month and depression at the end were responsible for two periods of disturbed weather during October. The low pressure area resulted in widespread rain on the 1st and 2nd, which became heavier and concentrated in the south-western parts on the 3rd and 4th. On the 3rd about 20 stations recorded falls over 5 inches. On account of these rains floods were experienced in the low-lying areas of the south-west quarter, Kelani Ganga rising above the minor flood level (5 feet) on the 7th and 8th. The depression caused strong winds and rough seas from 29th to 31st, with moderate rain in the south-western parts on the 31st. The weather during the other days was mainly of the inter-monsoon type, with scattered evening thunder activity. Dry weather prevailed over the whole Island on the 6th, 7th and 17th. The greater monthly totals of rainfall occurred in the south-western mid-country, where the aggregates at several stations exceeded 25 inches, the highest being 35.40 inches at Weweltalawa Estate (Yatiyantota), 32.19 inches at Padupola and 31.78 inches at Kenilworth Estate (Ginigathena). From this region there was a gradual decrease in rainfall, monthly totals at the south-western coast stations being of the order of 10 to 15 inches. Over a greater part of the rest of the Island the rainfall ranged from 5 to 10 inches. Least rain occurred in Puttalam, Mannar and Hambantota Districts, where at several stations the monthly totals were below 2 inches. The rainfall was below normal over a greater part of the Island, the bigger deficits (of the order of 5 to 8 inches) occurring in Puttalam and Mannar Districts and in the lee of the hills. Excesses occurred in the northern parts of the south-west quarter and in Batticaloa District.

Depressional activity which is a normal feature in November was conspicuous by its absence during November. Consequently, the rainfall experienced in the dry zone areas, comprising the North-Central Province and Vavuniya District, was below expectations. As rainfall was below normal in October too, and as October and November are two of the rainiest months for these regions, there is a possibility of acute drought conditions occurring there again next year, if adequate rainfall is not experienced in December. The weather that prevailed

during November was mainly of the inter-monsoon type, with fairly extensive thunder activity. Although the resulting rainfall was generally widespread, it occurred with greater frequency only among and around the central hills. North-east monsoon conditions were in evidence as from the 27th, with light to moderate north-easterly winds over the Island and moderate monsoon rain in Batticaloa District and neighbourhood. The rainfall for the month was heavier among and around the central hills and in the south-western mid-country, where the totals ranged generally from 15 to 30 inches. It was heaviest in Rangala area, St. Martin's (Lower) Estate aggregating as much as 45.10 inches, Hendon Estate 42.89 inches and Madugoda 40.04 inches. Least rain occurred in the north-western parts and in the neighbourhood of Hambantota, where the monthly totals were only of the order of 5 inches or so. The rainfall was appreciably above normal among and around the central hills, several stations, chiefly in the north-eastern hill-country, recording excesses over 10 inches. It was generally below normal in the northern half of the Island and at many coast stations in the southern half.

Ordinary north-east monsoon weather prevailed over the Island during December. The winds were however mainly dry except in Rangala area, where rainfall was experienced almost daily with many daily falls of over an inch. Over the rest of the Island the weather was mostly dry during the period 8th to 16th, and again, from 18th to 20th. A wet spell lasting over a week occurred towards the end of the month (21st to 28th) on account of a low pressure wave in Comorin area. This rainfall was moderately heavy from 24th to 26th, many daily falls over 3 inches being recorded. Fairly widespread rain occurred earlier on the 6th and 7th too, on account of another low pressure wave. The rainfall was heaviest in the north-eastern hill-country, where several stations recorded monthly totals over 25 inches, the highest being 42.34 inches at Madugoda, 40.07 inches at Iddumekelle Estate and 35.14 inches at Hendon Estate. In the north-eastern low-country and in parts of Galle and Kalutara Districts the rainfall ranged from 10 to 15 inches, while it was least (below 5 inches) in the south-western hill-country and in North-Western Province. The rainfall was below normal over a greater part of the Island, deficits being mainly of the order of 2 to 5 inches. Greater deficits occurred scattered in the north-eastern low-country. Excesses were found in the north-eastern hill-country and along the southern and south-western coasts.

D. T. E. DASSANAYAKE,
Director.

	October								
	Temperature				Humidty		Ranfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of days
Anuradhapura ..	90·6	+1·7	73·6	+0·1	70	93	3·80	−5·92	18
Badulla ..	82·9	+0·1	65·7	+0·2	71	95	6·86	−2·03	15
Batticaloa ..	86·6	−0·4	75·0	−0·3	72	86	10·52	+3·33	19
Colombo ..	83·0	−1·9	74·2	−0·6	86	95	14·21	+0·50	22
Diyatalawa ..	76·2	−0·1	60·6	+0·1	77	89	7·76	−1·42	24
Galle	81·4	−1·6	74·5	−1·0	85	90	13·39	+1·34	26
Hambantota ..	85·8	−0·4	75·9	+0·6	77	86	2·14	−2·62	8
Jaffna	84·4	−1·3	77·4	−0·2	74	84	12·13	+2·93	17
Kandy	81·2	−4·2	68·0	0	72	87	9·69	−1·92	20
Kankesanturai ..	86·4	−0·6	76·3	−1·0	77	91	5·86	−3·76	18
Kurunegala ..	85·7	−1·5	73·5	+0·3	76	93	9·17	−5·69	21
Mannar	86·1	−0·8	78·1	+0·8	77	84	1·87	−4·71	11
Nuwara Eliya ..	67·2	−0·4	54·0	+1·8	82	88	7·51	−2·25	22
Puttalam ..	87·8	+1·5	76·4	+0·8	69	84	1·55	−5·88	8
Ratmalana ..	84·2	−1·0	74·8	−0·1	76	86	11·86	−1·34	25
Ratnapura ..	85·8	−1·3	72·5	−0·3	79	93	16·99	−1·02	23
Trincomalee ..	88·0	0	75·5	−0·1	72	86	9·94	+0·39	19

	November								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of days
Anuradhapura ..	86·9	+1·1	71·6	+0·2	80	98	9·12	−1·55	22
Badulla ..	79·9	+0·6	65·7	+0·3	78	95	14·08	+3·83	24
Batticaloa ..	83·7	−0·5	74·1	−0·1	80	90	13·33	−0·53	20
Colombo ..	85·0	−0·2	73·0	−0·3	80	98	11·22	−1·87	23
Diyatalawa ..	75·3	+1·0	59·8	0	84	97	13·40	+2·98	27
Galle	83·4	−0·2	73·6	−0·6	81	90	16·17	+4.16	20
Hambantota ..	85·8	+0·4	74·2	+0·2	78	93	3·44	−4·13	13
Jaffna	84·4	+0·3	75·4	+0·6	76	88	11·40	−5·87	19
Kandy	83·7	+0·8	67·7	+0·3	72	90	14·06	+3·36	23
Kankesanturai ..	84·3	+0·1	75·1	−0·4	81	93	16·78	−0·36	22
Kurunegala ..	87·6	+0·7	71·8	−0·1	74	95	14·14	+1·75	20
Mannar	85·1	+0·5	76·1	+0·4	77	88	10·70	+0·51	20
Nuwara Eliya ..	69·8	+2·0	50·5	−0·6	82	90	12·47	+3·28	24
Puttalam ..	87·3	+1·7	73·7	+0·6	71	90	12·29	+2·16	17
Ratmalana ..	86·3	−0·1	73·6	+0·8	71	88	5·83	−1·29	22
Ratnapura ..	89·4	+1·6	72·1	−0·1	77	93	16·43	+1·64	27
Trincomalee ..	84·6	+1·0	76·1	+1·3	77	84	12·76	−1·18	19

	December								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of days
Anuradhapura ..	85·0	+1·8	68·7	−1·4	77	95	5·44	−2·08	16
Badulla ..	76·0	−0·6	63·8	−0·7	76	91	10·95	−0·28	20
Batticaloa ..	82·1	+0·2	73·5	−0·1	73	88	9·21	−7·78	17
Colombo ..	86·5	+1·0	71·5	−0·8	72	93	7·15	+1·54	11
Diyatalawa ..	70·8	−0·3	58·1	−0·5	82	94	7·06	−1·01	22
Galle	83·2	−0·4	72·9	−0·4	77	93	7·75	−0·07	15
Hambantota ..	85·7	+1·1	72·9	−0·1	72	88	6·37	+0·76	12
Jaffna	83·0	+0·5	72·2	−0·9	71	85	11·59	+1·20	14
Kandy	82·2	+0·4	64·6	−1·3	67	86	6·40	−2·47	13
Kankesanturai ..	82·7	—	75·2	+0·4	76	82	7·44	−2·30	12
Kurunegala ..	86·0	+0·3	69·5	−1·2	69	95	6·72	−0·06	13
Mannar ..	83·1	+0·3	75·5	+0·6	73	82	7·14	−0·65	14
Nuwara Eliya ..	67·0	−0·7	47·8	−1·2	78	90	4·95	−2·86	14
Puttalam ..	86·7	+2·0	70·5	−0·7	66	90	4·35	−1·20	10
Ratmalana ..	87·8	+1·5	71·8	+0·1	65	85	9·02	+2·37	12
Rainapura ..	89·8	+1·8	70·7	−0·9	70	93	5·71	−3·41	13
Trincomalee ..	81·6	+0·5	76·5	+1·6	72	77	9·12	−3·88	16